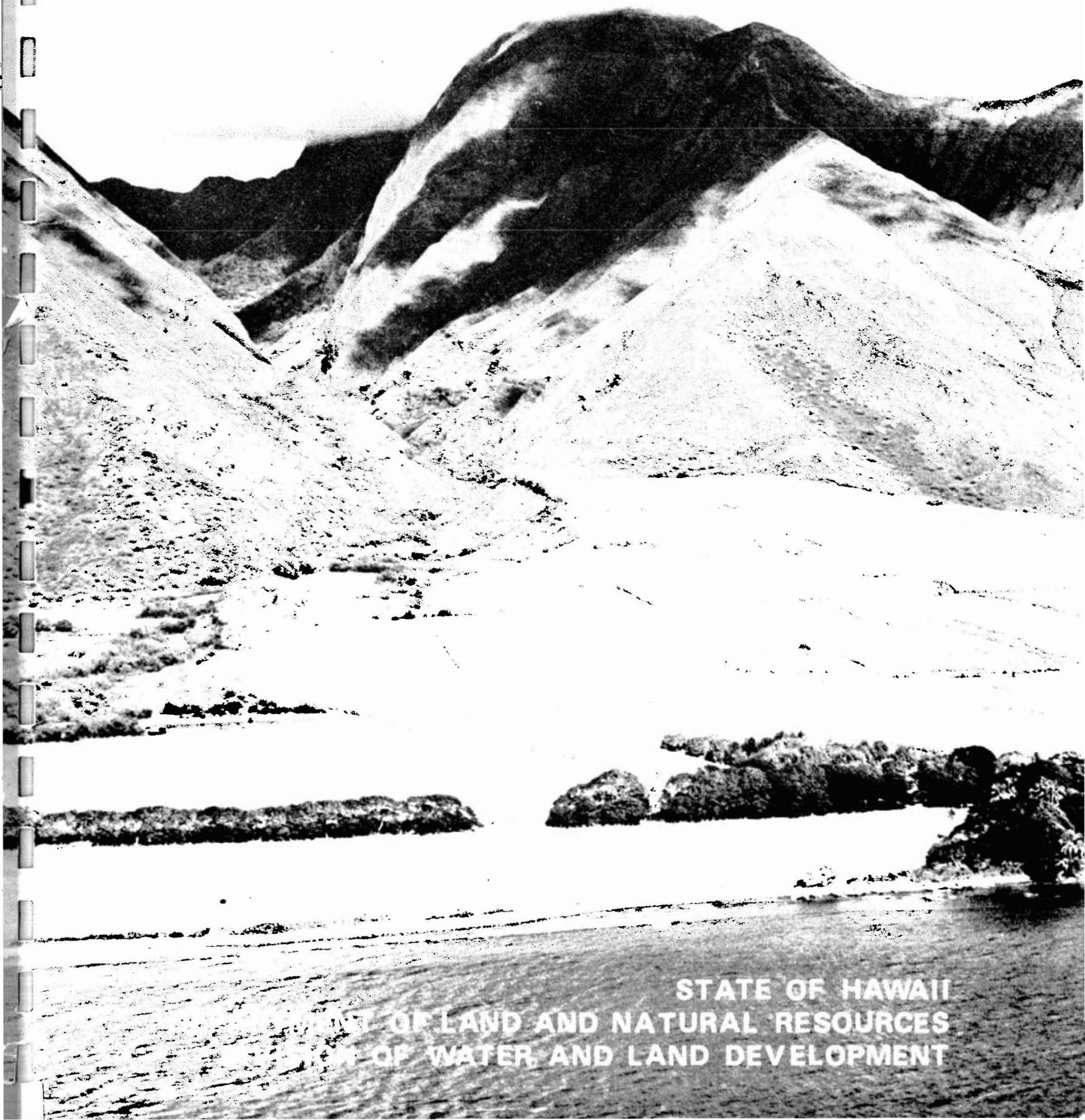


A WATER SOURCE DEVELOPMENT PLAN FOR LAHAINA DISTRICT

ISLAND OF MAUI

REPORT R33



**STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
BUREAU OF WATER AND LAND DEVELOPMENT**

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DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF WATER AND LAND DEVELOPMENT**



**BELT, COLLINS AND ASSOCIATES, LTD.
HONOLULU, HAWAII**

NOV. 1969

Belt, Collins and Associates, Ltd.



Engineers, Planners and Landscape Architects

1402 Kapiolani Boulevard, Honolulu, Hawaii 96814, Phone 949-4767

October 27, 1969

Mr. Robert T. Chuck
Division of Water & Land Development
Department of Land & Natural Resources
State of Hawaii
Honolulu, Hawaii 96809

Dear Mr. Chuck:

In accordance with the terms of our contract, dated October 22, 1968, we are pleased to submit this engineering study for the development of water resources for the Lahaina District on the island of Maui.

After investigation and evaluation, it was determined that high level ground water holds the best promise for a stable amount of high quality domestic water to meet the projected demands of the foreseeable future. It is to be noted that implementation by an orderly incremental development of resources through planning, investigation, design and construction as the demand rises rather than a "one shot" capital improvement expenditure would be advisable.

We would like to express our appreciation for assistance rendered us by members of the staff of the United States Geological Survey, Maui County Board of Water Supply, Amfac, Inc., Maui Land & Pineapple Company and especially the excellent cooperation and invaluable help extended to us by members of your staff during the preparation of this study.

Very truly yours,


James R. Bell

WDN:gk

Attach.

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I SUMMARY

Purpose and Scope of Work

The purpose of this study is to delineate a water source development and transmission plan which will meet the domestic urban water requirement of the Lahaina District of West Maui, taking into account the continuing irrigation needs of agriculture.

The scope of work includes the review of existing available data that will correlate available sources with present and future needs, the determination of the alternatives of physical development that will meet the needs as they arrive, and the cost of the development most compatible to the needs and growth pattern anticipated.

Limiting Criteria

The only specified limitation of the study is that the values and timing of urbanized need be those of the "701" study for West Maui, prepared by Muroda & Tanaka, Inc., dated December, 1968, and entitled, "A General Plan for the Lahaina District, County of Maui."

Need for a Water Plan

The Muroda & Tanaka "701" study projects substantial urban growth in the Lahaina District. A water plan is needed to provide a guide line for planning, designing, and constructing a water system, or systems, economically viable, reasonably flexible and sufficiently incrementalized to meet the water needs of the area as they arise.

Characteristic of the Study Area

The Lahaina District is the southwestern portion of the West Maui volcanic dome. The district comprises about half of West Maui.

The West Maui dome is formed primarily of primitive olivine basalts. Elevation varies with general uniformity from approximately 5,800 feet down to sea level. Geologically the rocks of West Maui are the Honolua andesites and trachytes and the Wailuku basalt. The latter being the most important as a water bearing aquifer.

Rainfall patterns are relatively uniform with trade winds orographic precipitation at a maximum at higher elevation and at a minimum near sea level. Annual precipitation ranges from as much as 400 inches to as low as 15 inches. Annual isohyetal gradients are steep and thus subject to negligible change in position with the acquisition of additional statistical data. The range of monthly rainfall at selected gaging stations is substantial, particularly at lower elevations.

Land Use

Present land use of the Lahaina District is as shown in the following table.

Conservation (Forest Reserve)	21,800 Acs.
Agricultural	26,600 Acs.
Urban	2,800 Acs.
Others	10,100 Acs.

Future land use as reflected in the "701" report for the Lahaina District increases the urban use to approximately 4,670 acres. This increase in acreage for urban use will come from agricultural and other present land uses.

Existing Water Systems

There are basically two categories of existing water systems but with some overlap in type of use. The categories are agricultural and domestic.

The primary agricultural system is that of Amfac's Pioneer Mill Co. Serving the Pioneer Mill system and its own agricultural and domestic requirements is the diversion, transmission, and distribution system of Maui Land & Pineapple Company.

There are six domestic systems--two of which are private systems developed primarily for irrigation purposes but also providing for the domestic requirements of the various plantation villages and the Kaanapali Resort; and four County systems which serve Lahaina, Honokowai, Alaeloa-Kahana, and Honokohau. The Honokowai, Alaeloa-Kahana, and Honokohau systems presently obtain water from Maui Land & Pineapple Co.

Total average domestic consumption in the County systems is 784,000 GPD.

Anticipated Additional Water Demands

The growth in domestic water requirements in the Lahaina District is expected to occur primarily as a result of the increasing urbanization of the area's resort-oriented economy. The categories of significance are residential, apartment, hotel, commercial, industrial and public. Included within these categories are golf course irrigation and landscape irrigation.

Total use in all categories is expected to grow from approximately 2.7 MGD in 1970 to 14.9 MGD in the year 2000. While urban

use will measurably increase, agricultural requirement should remain fairly consistent, assuming no significant change in the scope of pineapple or sugar cane operations. Such an assumption is basic to the projected growth as expressed in the "701" report.

Urban water demand for the district is projected to be 9.7 MGD by 1985--about a four-fold increase over present use.

Amfac projects a 1.8 MGD greater requirement for 1980 than is derived from the Muroda & Tanaka report due to a more optimistic view of development in the Lahaina and Kaanapali areas. Both estimates are based on identical unit values of use except for the residential-apartment demand.

The unit values of use adopted for this report are based on a review of past experience in the Kaanapali area and are:

Residential-apartment	600 GPD/Unit 750(Amfac)
Hotels	550 GPD/Room
Commercial	5,000 GPAPD*
Industrial	4,000 "
Public	4,000 "
Schools	2,000 "

*GPAPD = gallons per acre per day

A major increase in requirements will occur by 1975 with demand rising to better than 5.0 MGD for urban use.

Water Availability

The primary sources of new developable water in the Lahaina District are from ground water sources. This report concludes that high level (dike held) ground water holds the best promise

for a stable amount of high quality domestic water and that such resources are subject to an orderly incremental procedure of "proving up", planning, design and construction consistent with "as needed" rather than "one shot" capital improvement expenditures. Should the necessary field drilling investigations have results adverse to high level ground water development, it is concluded that basal ground water sources should be utilized.

Surface water sources, both rainfall runoff and base flow, have been developed in the district to the extent that further development is "economically" an inferior choice to the ground water approach. The surface waters available for use are either peak storm runoff or limited base flows at remote locations.

Out-of-area sources, sea water treatment and waste water recovery are generally economically unattractive.

Water budgets have been prepared for three areas: Area A - Honokohau East through Honokeana basins; Area B - Kahana East through the Launiupoko basin; and Area C - consisting of Olowalu and Ukumehame basins. These budgets show ground water recharge for a monthly median rainfall of the following values:

Area A	-----	29 MGD
Area B	-----	35 MGD
Area C	-----	6 MGD

In the cases of areas B & C, recharge is primarily effected with water from the upper areas, as rainfall in lower areas is not sufficient to meet evaporation transpiration requirements.

By developing high level ground water and taking advantage of the averaging effect of dike storage, it is considered that an amount sufficient to meet the needs of the year 2000, an additional 14 MGD, can be drawn without adverse consequences even in a critical water period, provided the withdrawal is of a dispersed character as proposed in the recommended development plan.

The precise location of wells must be established by more detailed field investigation and test drilling programs.

Plan for Water Development

The recommended plan is to provide ground water from Kanaha, Honokowai, Honokahua and Honolua Valleys to meet the water needs of the Lahaina District in the foreseeable future. The ground water would be developed with a series of vertical wells as the demand arises. Reservoirs to store the developed water would be constructed along with transmission lines to the service areas. The elements of the plan would be developed in stages to meet the projected demand to the year 2000.

II INTRODUCTION

With the advent of Statehood, Hawaii has experienced an ever increasing activity in the tourist industry and in second living unit interest by Mainland investors. Maui is the outer island which has probably experienced the greatest degree of growth in the vacation oriented economy of Hawaii. The Lahaina District of Maui, shown on Plate 1, has shown a greater degree of concentrated growth than any other area on the island. The Lahaina District, which includes the town of Lahaina, the Kaanapali resort development and the shoreline development from Kaanapali to Kapalua Bay, is projected to grow at an increasing rate.

The pending urbanization of this area brings with it concerns for the basic services that will be required to serve the community. Foremost among the needs of the area is a stable, adequate and economical source of potable water for domestic use. Recognizing that available water supplies are always subject to competitive uses, a total concern for water includes that required for agricultural as well as urban use.

The State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development (DOWALD), in concert with the Board of Water Supply, County of Maui, has recognized the pending needs and has initiated this study to investigate the possible sources of water for future needs and formulate a general plan of development for serving them.

Present water needs for the Lahaina District are met by a series of systems, both private and public. The Board of Water Supply, County of Maui, has four separate systems in the Lahaina area. Amfac, Inc. has a separate system not only for irrigation

purposes but also for domestic use in the Kaanapali area. Maui Land & Pineapple Company, which has an extensive irrigation water development, not only provides water for its needs and for Pioneer Mill but also makes water available to the County of Maui for domestic purposes.

This study of necessity involves consideration of all the water sources and systems operational in or immediately adjacent to the Lahaina District.

From a flexibility and protection point of view, there would be an advantage in an integrated domestic water supply system. Where all sources are delivering to a common system, standby well requirements are somewhat lessened. Although not specifically shown on the development plan, it is contemplated that the Kapalua-Kahana-Honokowai-Kaanapali-Lahaina area will have an inter-connected transmission system which allows water from any of the domestic sources to supply the common transmission-distribution system.

III CHARACTERISTICS OF STUDY AREA

Geography

Climatology

Geology

Land Use

GEOGRAPHY

Maui is the second largest island of the Hawaiian archipelago. It lies in the midst of the Pacific Ocean between $21^{\circ} 02'$ and $20^{\circ} 35'$ north latitude and $155^{\circ} 59'$ and $156^{\circ} 42'$ west longitude. The island is approximately 48 miles long, has a width of approximately 26 miles at its widest point, and has an area of approximately 730 square miles. Maui lies 60 miles southeast of Oahu and about 60 miles northwest of the next island in the Hawaiian chain, Hawaii. Maui and Hawaii are separated by Alenuihaha Channel. Molokai, the next island to the northwest, and Maui are separated by Pailolo Channel.

The Lahaina District, the area under study, covers an area of slightly over 96 square miles on the northwest end of the island as shown on Plate 1. This is approximately 13 per cent of the total area of the Island of Maui.

The principal urban area is the town of Lahaina, capital of the Kingdom of Hawaii in Ancient Times. Other urban developments within the Lahaina District consist of presently expanding resort facilities following the coastline between Kaanapali and Kapalua Bay, and the numerous small communities of Honokohau, Honokahua, Kahana, Mahinahina, Honokowai, Puukolii, Mala, Wainee and Olowalu. Some of these plantation villages have been or are being encroached on or absorbed into expanding resort developments.

The seat of government, for the Lahaina District, as well as for the rest of the island, is the town of Wailuku, located to the northeast of the West Maui mountains. These mountains act as the common boundary between the Lahaina and Wailuku Districts.

CLIMATOLOGY

General

West Maui district has a climate typical of areas in the Hawaiian Islands sheltered from the prevailing northeasterly tradewinds. As elsewhere in the Hawaiian chain, the climate of the Lahaina District is substantially affected by topographic configuration. Differences in elevation and closeness of the mountain masses to the coastal area have a substantial impact, both on temperature and rainfall.

During the winter months of the year, the area is exposed to "Kona" rains, which are primarily from cyclonic storms. The rainfall received during a single cyclonic storm can exceed the amount of rainfall received during the balance of the year. The effect is that of superimposition of cyclonic patterns on a normal trade-wind regime. Maximums and minimums of rainfall can be widely diverse with maximums running to approximately 400 inches per year.

Temperature

The temperature within the study area varies with elevation. The low coastal areas are generally warm. For example, the mean annual temperature of Kaanapali, the site of major resort development for the area, is approximately 76°F. This is the highest mean annual temperature at any measuring station on the island. The minimum recorded temperature at Kaanapali is 47°F, while the maximum is 98°F. Average daily maximum is about 85°F, while average daily minimum is around 66°F.

Winds

The district is exposed primarily to the northeasterly trade-winds, as modified by the shielding effects of the West Maui mountains. As is the case with many leeward areas, the Lahaina District is subject to diurnal wind variation resulting from temperature changes over the land mass and the ocean plane. The down slope effect has given some reputation to areas such as Kaanapali of being "breezy".

Wind patterns are markedly different under conditions of "Kona", cyclonic storms and wind velocities have been known to rise to 50 - 60 miles per hour.

Rainfall

The predominant parameter of climatology in the study of the Lahaina District water supply is, of course, rainfall.

It is generally recognized that rainfall is a highly variable item within the West Maui area. It is recognized that mean annual rainfall within the district can vary from as low as 15 inches to as much as 400 inches, depending primarily on elevation. Plate 2 shows the distribution of mean annual rainfall as derived statistically from data available through 1968. The rainfall gradients (isohyets) as shown on this plate vary somewhat, but not importantly from isohyetal plots contained in previous reports. Data of this type should be taken "cum granu salis" because of the manner in which isohyetal patterns vary with statistical data available. The range in rainfall variation is effectively demonstrated on Plates 3 & 4 entitled, "Monthly Rainfall From Selected Rain Gages".

While generalizations are often made regarding rainfall patterns in lee areas in the Hawaiian Islands, there are periods in which these patterns are substantially upset. The examination of the aforementioned charts will make this evident. For example, Puu Kukui rain gage No. 380 shows a monthly rainfall ranging from approximately 10 or less inches for December to as much as 150 inches for December. It is also interesting to note for Puu Kukui rain gage that the average value of rainfall for each of the 12 months of the year is fairly close to 35 inches. This is consistent with the mean annual rainfall value of 400 inches. However, annual rainfall at this gaging station has ranged from as little as 232 inches to as much as 578 inches.

It is important to note, also, that the area above Elevation 1000 represents only 46 per cent of the total district area but represents 80 per cent of the rainfall of the Lahaina District.

To further exemplify the difficulty in evaluating rainfall, the following points are made:

- a. The range in recorded annual rainfall at Lahaina has a ten-fold variation from minimum to maximum value;
- b. The range at Kahoma intake has an approximate five-fold variation.

Evaluation of data indicates that variations between minimums and maximums are greatest at the lower elevations.

In arriving at the figure to be used as a preliminary value for gross average annual water replenishment for the Lahaina District,

The U.S. Geological Survey figure of 340 million gallons per day rainfall seems a satisfactory base point for the establishment of a preliminary water budget. Subsequent studies, referred to later, show somewhat different figures.

Surface runoff, basal ground water recharge, surface water diversion, high level ground water recharge all relate, although in different ways and with different parameters, to rainfall.

GEOLOGY

The factor second only to rainfall in importance in identifying sources of water in West Maui and methods of their development is geology.

The volcano of West Maui, the southwestern slope of which comprises the Lahaina District, is dissimilar in several respects to the other volcanoes of the Hawaiian chain. This dissimilarity has substantial impact on the nature of water sources and the means and methods by which these water sources can be developed. The dissimilarities between West Maui volcano and the other volcanoes are the more circular form, steeper dips, more large intrusive bodies, wider dikes and radial dikes, as described by Stearns and Macdonald, which have substantial bearing on the location of water sources, the quantitative extent of sources, their dependability, the migration of ground water and other elements, all pertinent to the development and exploration of both basal and high level ground water supply.

Generally, the West Maui volcano is defined as a dome of primitive olivine basalt, oval shield shaped. It was laid down in the

form of highly fluid pahoehoe and aa flows of moderate thickness. Puu Kukui, the highest point on West Maui, has an elevation of approximately 5788 feet.

Of considerable importance is the fact that the oldest and most predominant rocks on West Maui are the Wailuku basalts. These olivine basalts are permeable in character and are the present and future best sources of high level dike water as well as basal water. The overlying Honolua soda trachyte and andesites are considered to be poor aquifers as are the Lahaina picritic basalts.

One of the significant features of the geology of West Maui is the radial characteristic of the dike structures. As will be discussed later, this characteristic could have an impact on the conditions relating to ground water migration and basal water recharge.

Much of the coast of West Maui is covered by consolidated sedimentary rocks consisting of talus breccia, calcareous sands, marine conglomerates and other alluvial conglomerates. These also occur in the bottoms of major valleys. Beach sediments and younger alluviums are found primarily along the coast. All evidence available indicates that the basic source of domestic water supplies in the West Maui area will be the Wailuku rocks. Their highly permeable character, possibly greater than that of the Koolau series of Oahu, and their intrusion by impermeable dike barriers form the underground water compartments within which the major portion of developable water of highest quality is available.

LAND USE

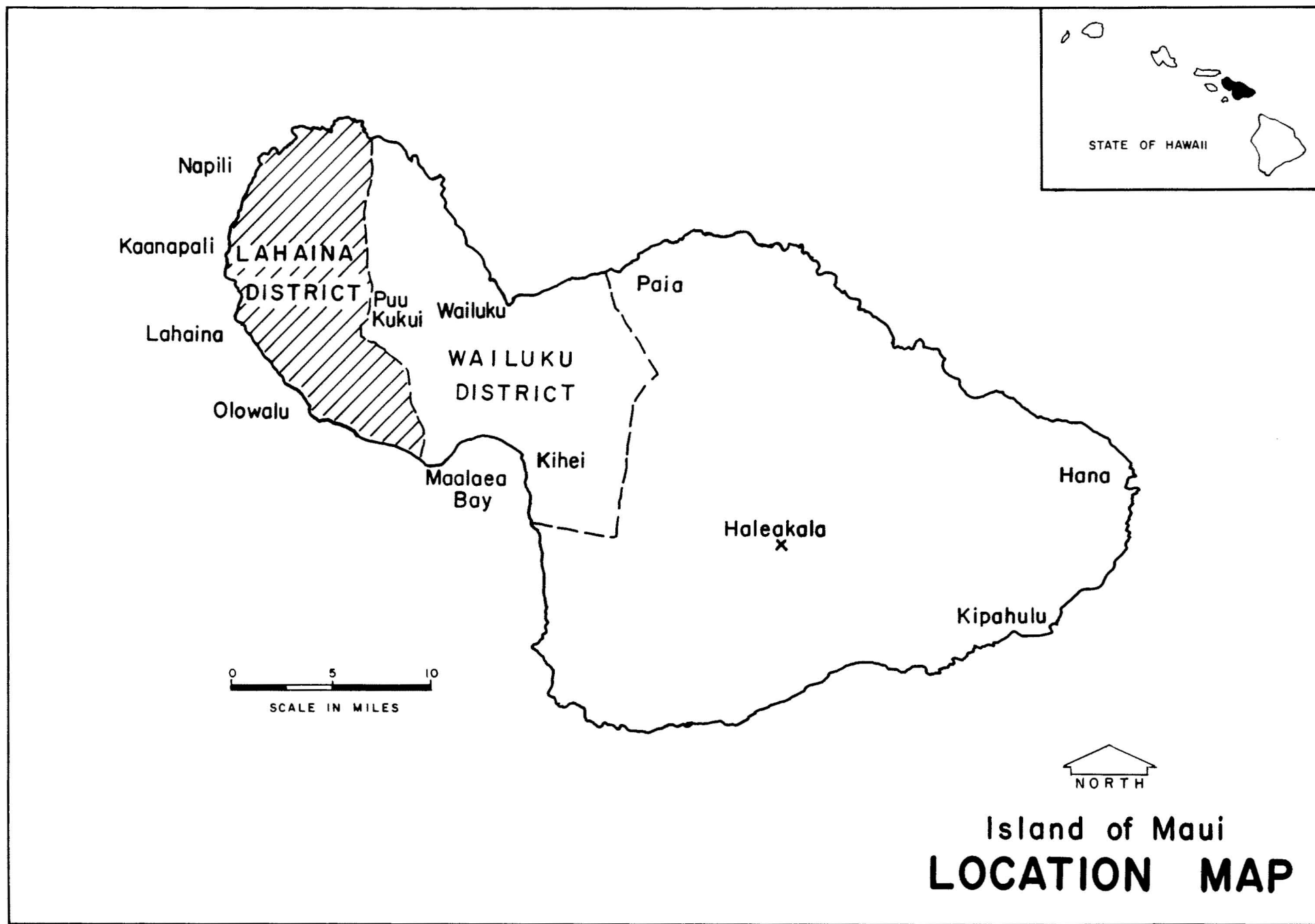
Existing

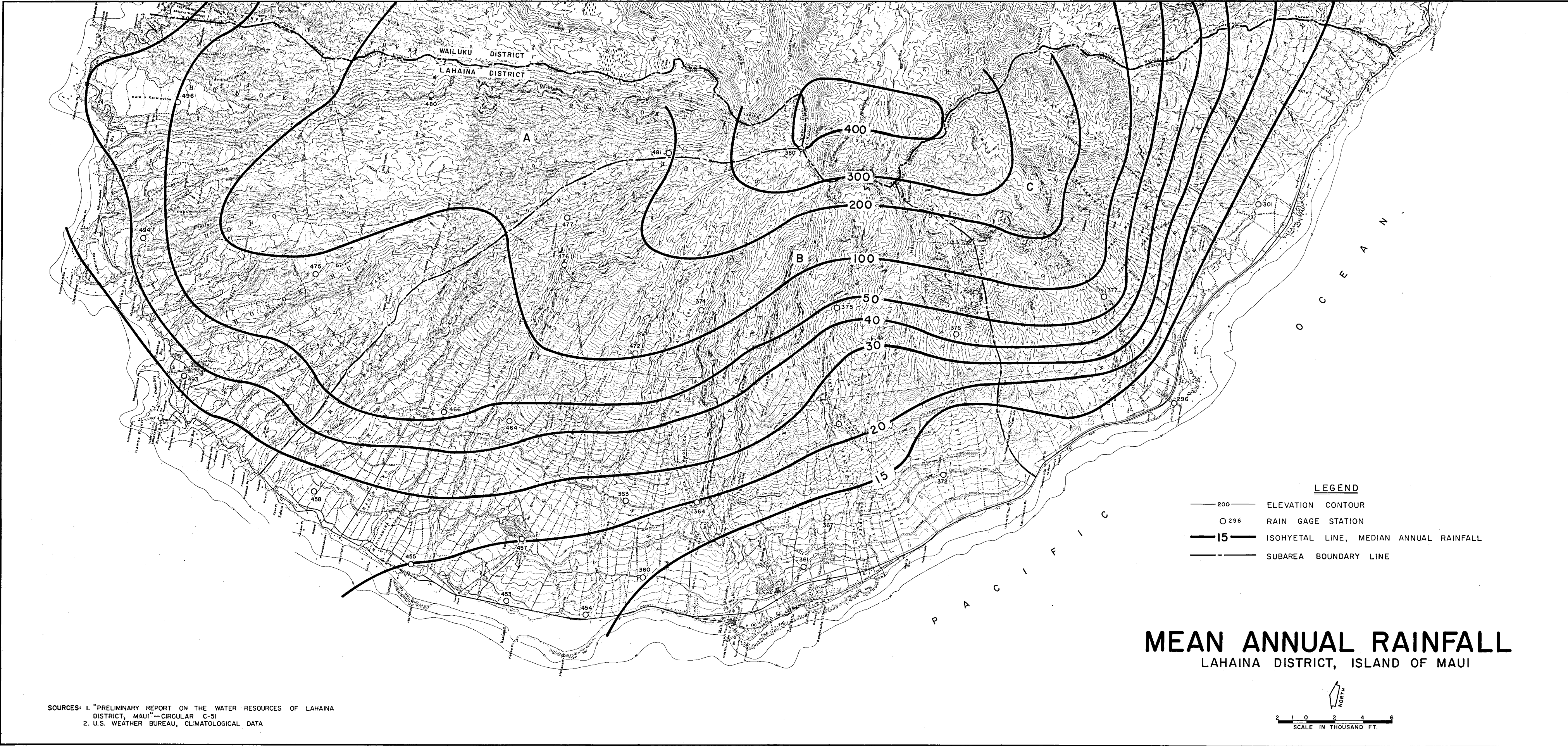
The existing land use of the Lahaina District, Island of Maui, is delineated on Plate 7. Approximately 35 per cent is in conservation (forest reserve), 44 per cent Agricultural, 5 per cent Urban and the balance is undefined.

The plates indicate the predominance of agricultural use in those lands that are subject to and suitable for development by man. The large area designated for forest reserve and the major portions of the unidentified areas between these lands and the sugar cane and pineapple land will probably stay in a natural state for an indefinite period in the future.

Future Land Use

The Maui County Planning Department has recently completed a land use study through the "701" grant. The resulting plan provides the framework for effecting an orderly development of the Lahaina District. Plate 13 sets forth the future land use pattern of the "701" study.

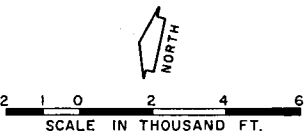




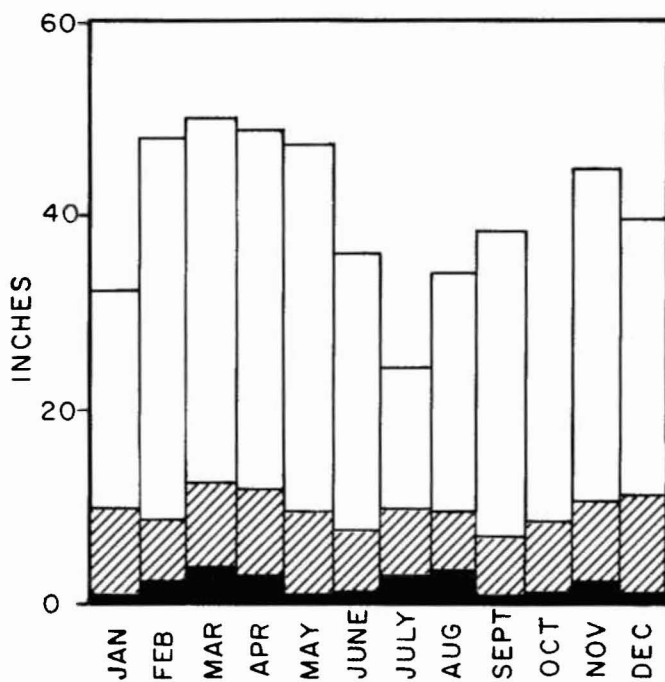
LEGEND

- 200 — ELEVATION CONTOUR
- 296 RAIN GAGE STATION
- 15 — ISOHYETAL LINE, MEDIAN ANNUAL RAINFALL
- - - SUBAREA BOUNDARY LINE

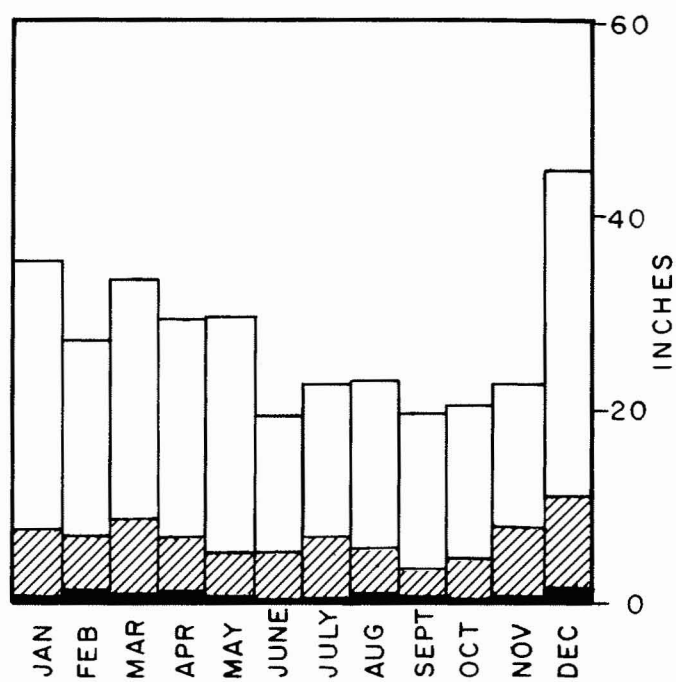
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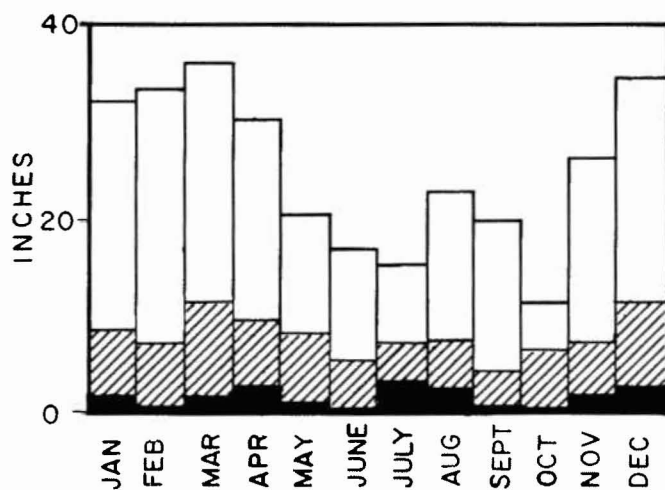
SOURCES: 1. "PRELIMINARY REPORT ON THE WATER RESOURCES OF LAHAINA DISTRICT, MAUI"—CIRCULAR C-51
2. U.S. WEATHER BUREAU, CLIMATOLOGICAL DATA



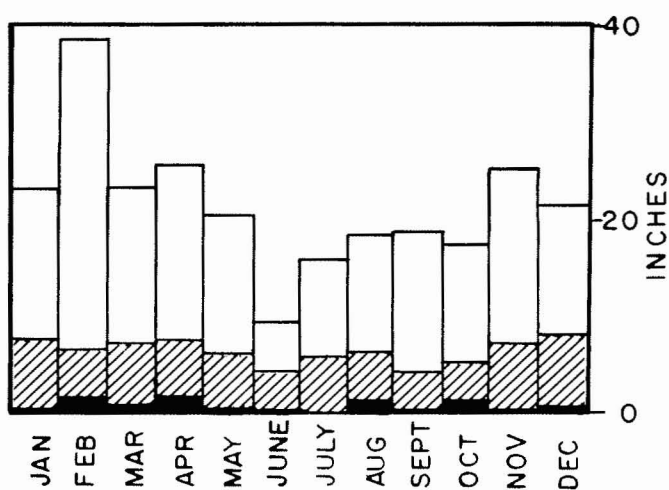
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KAHOMA R.G. #374

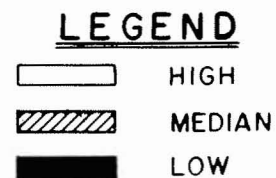


HONOKOWAI R.G. #476

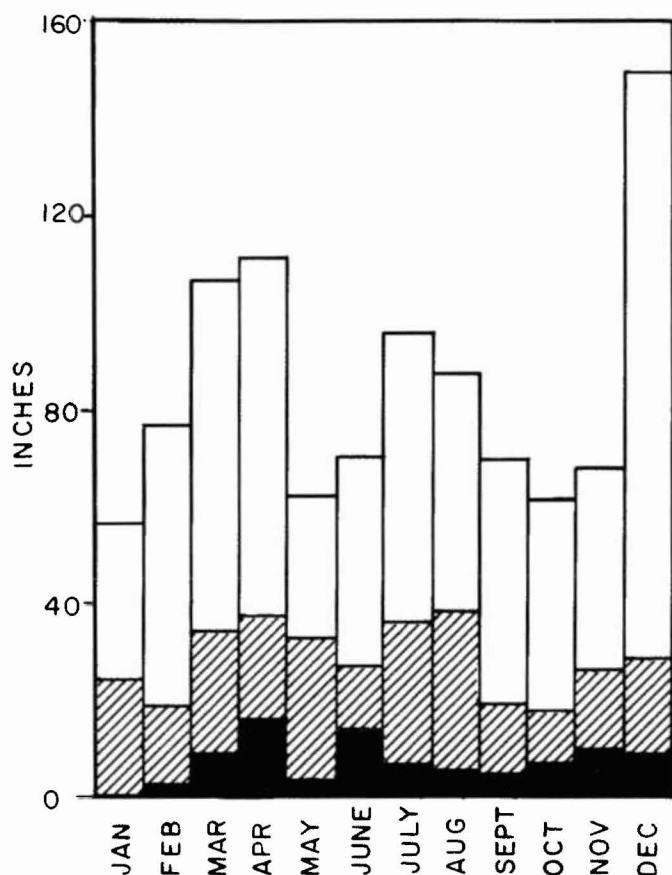


MOKUPEA R.G. #475

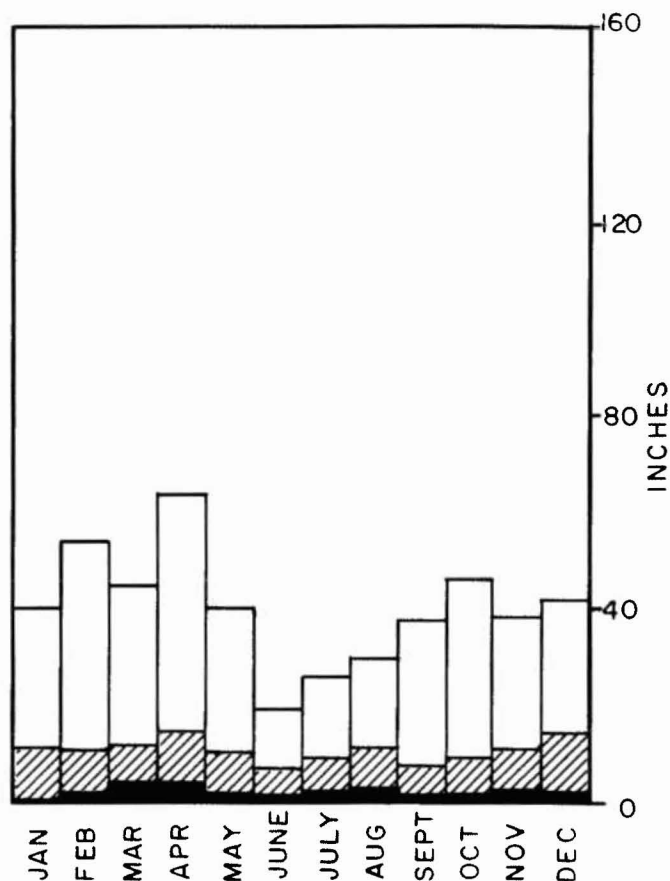
MONTHLY RAINFALL AT SELECTED RAIN GAGES



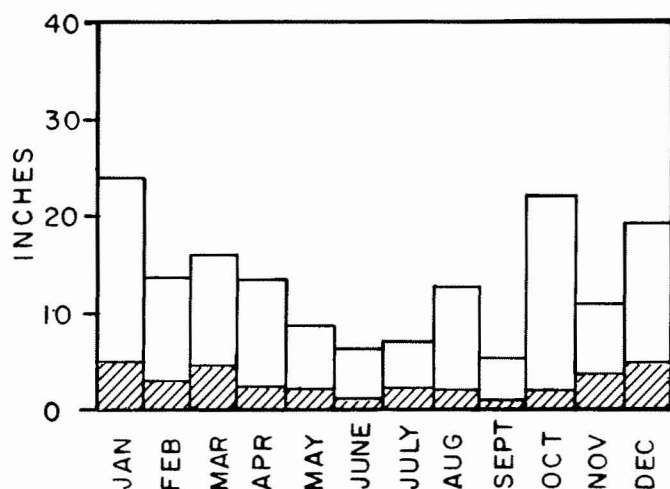
SOURCES: 1. U.S. WEATHER BUREAU, CLIMATOLOGICAL DATA
2. RAINFALL OF THE HAWAIIAN ISLANDS



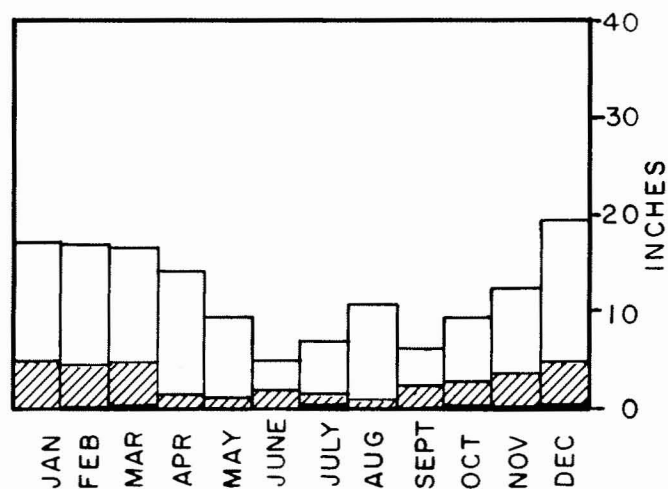
KUKUI R.G. #380



HONOKOHAU R.G. #480

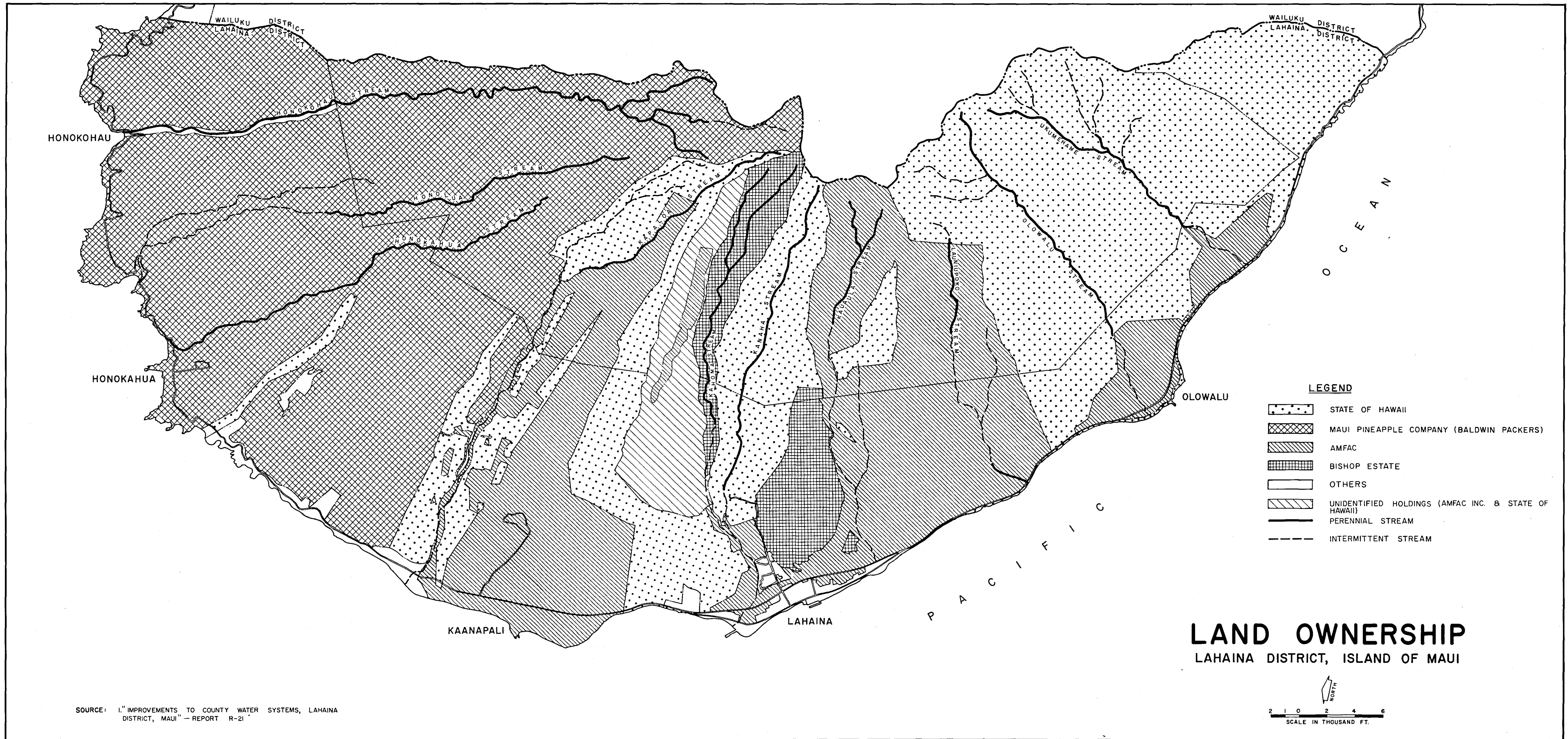


LAUNIUPOKO R.G. #376



KAUULA R.G. #375

MONTHLY RAINFALL AT SELECTED RAIN GAGES





IV HISTORY OF WATER

Investigation

Development

INVESTIGATION

Studies and investigations of the water resources for the Lahaina District have been conducted previously by various persons and agencies. Some of the pertinent studies made are:

- a. Geology and Ground Water Resources of the Island of Maui, by H. T. Stearns and G. A. Macdonald, 1942.
- b. Preliminary Report on the Water Resources of the Lahaina District, Maui, by the U. S. Geological Survey, 1969.
- c. Improvements to County Water Systems, Lahaina District, Maui, (Report R-21) by the Department of Land and Natural Resources, 1963.
- d. Ground Water Supplies for Pioneer Mill Company, Maui, by H. T. Stearns.
- e. Data on ground and surface water compiled by DOWALD.

The evaluation of the water resources for this report relies heavily on the many investigations conducted previously and the data compiled throughout the years by the U. S. Geological Survey.

DEVELOPMENT

Water development in the Lahaina District was started by the early Hawaiians with the diversion of stream flows for use in the inland taro patches in some of the major stream valleys. Fields were also maintained in the coastal reaches of the perennial streams. Water rights of 1 MGD for the growing of taro are still observed on Honokohau Stream. Domestic water was obtained from coastal springs or from wells dug near coastal springs.

From early 1900, stream flows from the perennial streams were diverted by ditches and tunnels for the cultivation of sugar cane. Subsequently, eleven tunnels, of which two are dry, were driven to tap high level ground water and thus appreciably increased the base flows of streams. The water development tunnels are shown on Plate 8 with pertinent data summarized in Table 1. Driving tunnels into the dike compartments on the downstream side of the dike system where the water had already been drained by the stream and random tunneling to follow "vein of water" tapped water impounded behind dikes of dense rocks were two major errors committed in the development of high level tunnels, according to H. T. Stearns. As soon as storage within these compartments was depleted, the tunnel yielded water equal only to the recharge above the area from rainfall.

Early in the century, twelve Maui-type wells, a name applied to shafts excavated to the basal lens with skimming tunnels, were constructed along the coastal areas by the two plantations to supplement the surface water resources. The locations of these wells are shown in Plate 8 with the pertinent data summarized on Table 2.

There are also several drilled and dug wells along the coastal area. The salinity of the basal ground waters from these wells is greater than the recommended health standard for domestic consumption.

In 1962, DOWALD drilled an exploratory well about 1.5 miles from the coast near Lahainaluna High School at an elevation of 441

feet. Results of the pumping test indicated a salinity of 118 ppm with a drawdown of 1.2 feet. The yield was considered good, and subsequently, the Maui County Board of Water Supply drilled another well nearby. Both wells are presently used to supplement the surface water from the Kanaha Stream. Plate 10 illustrates the result of the five-day pumping test.



SOURCES: 1. "PRELIMINARY REPORT ON THE WATER RESOURCES OF THE LAHAINA DISTRICT, MAUI" — CIRCULAR CSI
2. "IMPROVEMENTS TO COUNTY WATER SYSTEMS, LAHAINA DISTRICT, MAUI" — REPORT R-21

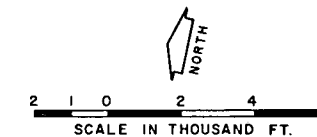


TABLE 1
WATER DEVELOPMENT TUNNELS

Tunnel No.	Name of Valley	Owner	Elevation Above M.S.L. (ft.)	Length of tunnel (ft.)	Daily flow M. G. D.
13	Olowalu	P.M. Co.	1,710	3,000	0.1
14	Olowalu	P.M. Co.	775	-----	Dry
15	Launiupoko	P.M. Co.	1,425	1,320	0.1
16	Kauaula	P.M. Co.	2,920	656	2.0
17	Kahoma	P.M. Co.	1,923	2,500	Dry
18	Kahoma	P.M. Co.	1,984	3,080	1.9
19	Kahoma	P.M. Co.	2,350	739	0.01
20-A	Honokowai	P.M. Co.	1,700	1,250	1.76
20-B	Honokowai	P.M. Co.	1,600	1,050	0.58
21	Honokohau	M. P. Co.	880	720	2.25
22	Honokohau	M. P. Co.	900	1,015	1.81

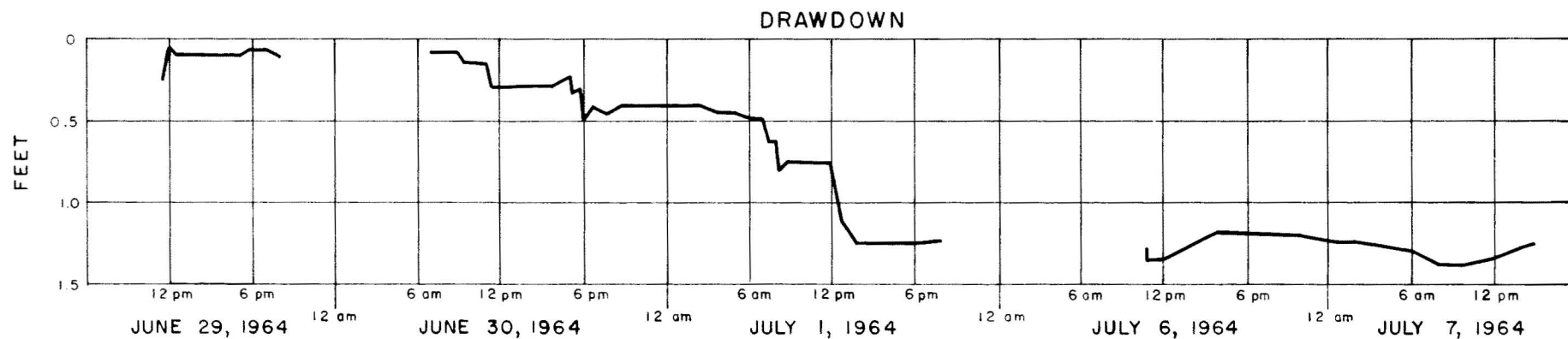
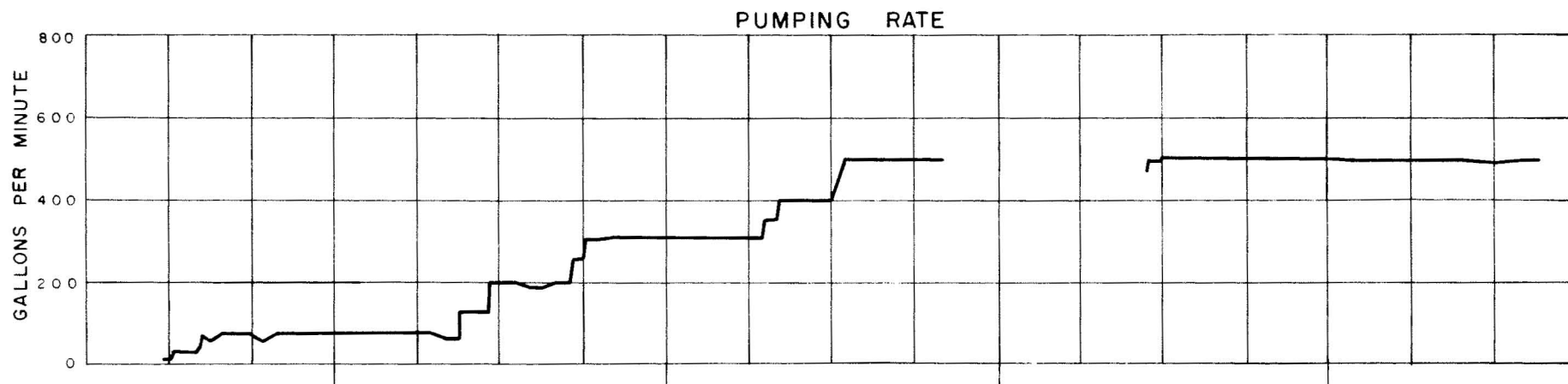
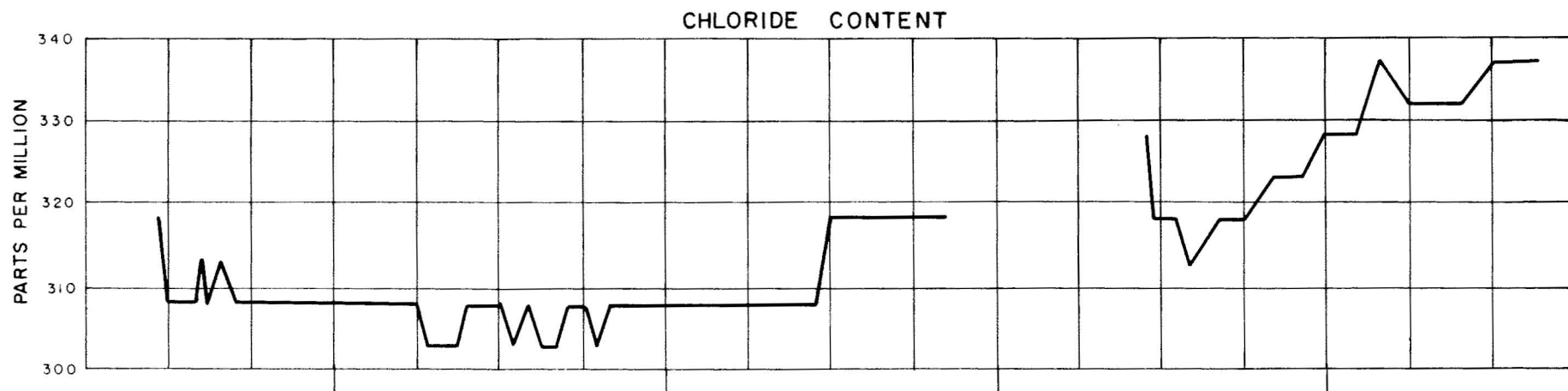
- Sources:
1. "Preliminary Report on Water Resources of the Lahaina District, Maui" -- Circular C51.
 2. "Geology and Ground Water Resources of the Island of Maui, Hawaii" by Harold T. Stearns and Gordon A. Macdonald.

TABLE 2
MAUI TYPE WELLS

U. S. G. S. No.	Name of Well	Owner	Elevation Above M. S. L. (ft.)	Depth of Shaft (ft.)	Pumping Capacity (M. G. D.)	Draw- Down (ft.)	Static Water level (ft.)	Salt (P. P. M.)
1	Alaeloa	M. P. Co.	244	245	0.03	0	2.0	249
2	Honokowai	M. P. Co.	65	65	5.00	2.0	2.0	520
3	Kaanapali	P. M. Co.	27	25	15.00	0.7	2.0	831
4	Hahakea	P. M. Co.	14	12	5.00	0.5	1.5	727
5	Kahoma	P. M. Co.	322	323	10.00	0.7	2.2	312
6	Wahikuli	P. M. Co.	26	27	5.00	0.7	1.5	623
7	Mill	P. M. Co.	34	39	10.00	3.0	3.0	1,039
8	Lahaina	P. M. Co.	30	31	10.00	1.0	2.0	623
9	Lahaina	P. M. Co.	30	31	13.90	1.0	2.0	831
10	Olowalu	P. M. Co.	165	300	5.25	1.0	3.5	312
11	Olowalu	P. M. Co.	20	20	3.00	2.0	2.0	187
12	Ukumehame	P. M. Co.	79	143	4.75	0.7	6.0	468

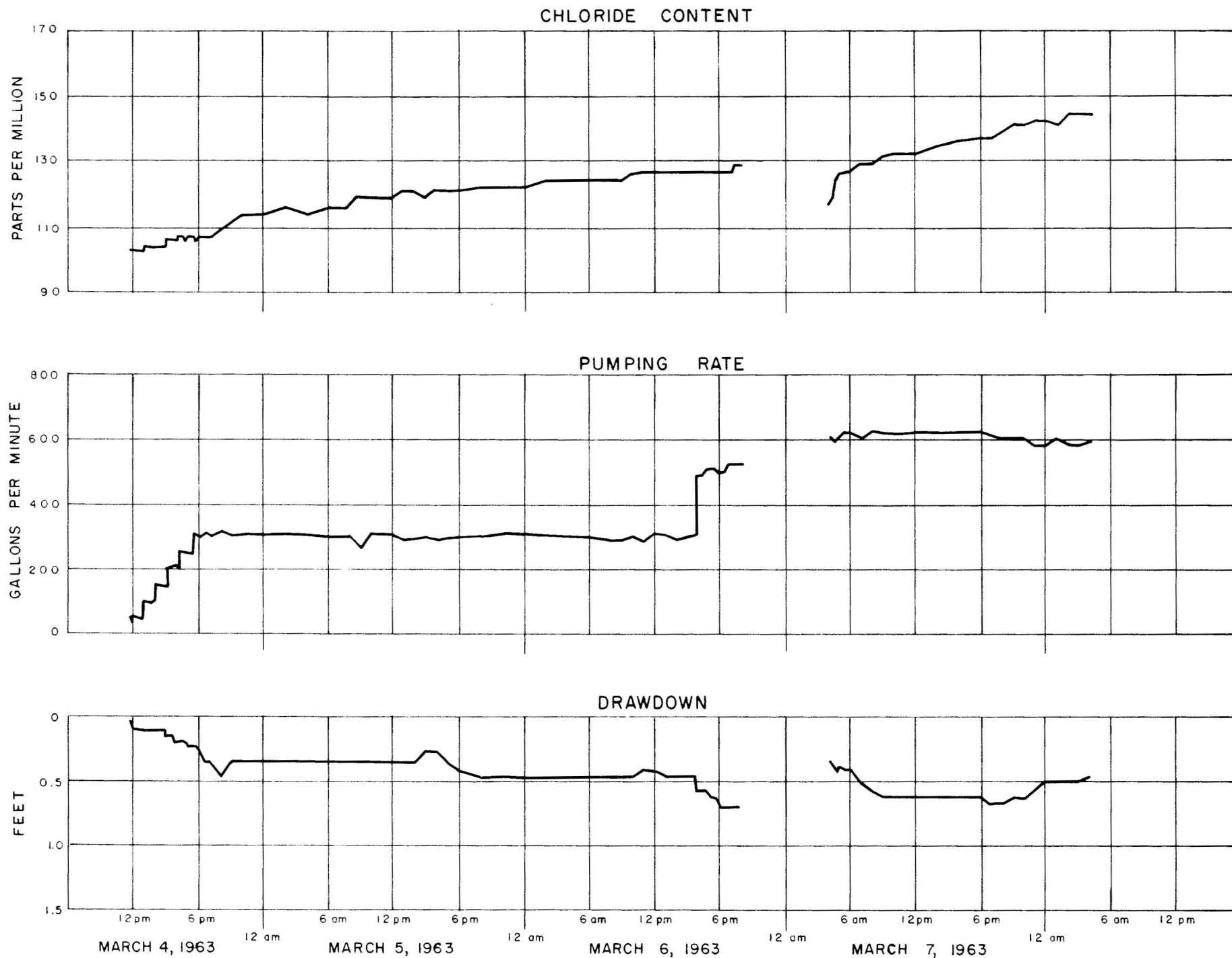
- Source:
1. "Geology and Ground Water Resources of the Island of Maui"
by H. T. Stearns and Gordon A. Macdonald.
 2. "Improvements to County Water Systems, Lahaina District, Maui" --
Report R-21.

Note: Salt content converted from grains per gallon by using conversion factor of 10.39.



PUMP TEST, ALAELOA WELL NO. 318 (EXPLORATORY)

SOURCE: 1. "SUMMARY OF DRILLING LOG AND PUMPING TEST FOR ALAELOA WELL NO. 318" — CIRCULAR C35



PUMP TEST, LAHAINA WELL NO. 292

SOURCE: I. "IMPROVEMENTS TO COUNTY WATER SYSTEMS
LAHAINA DISTRICT, MAUI" — REPORT R-21

V. EXISTING WATER SYSTEM

Irrigation Water Systems

Domestic Water Systems

For convenience in this study, the water systems now serving the Lahaina District are grouped into two categories: those providing water for domestic use and those providing water to the plantations for agricultural use. The irrigation systems owned by Pioneer Mill Company, together with the transmission facility owned by Maui Land & Pineapple Company, are shown on Plate 11. The four County systems and the Kaanapali private system owned by Amfac, Inc. are shown on Plate 12.

IRRIGATION WATER SYSTEMS

The largest water system in the district has been developed for irrigating the sugar crop lands of Pioneer Mill Company. The system utilizes surface water, high level ground water, and saline basal ground water. Facilities include ditches, flumes, reservoirs, and Maui-type wells. An average of 25 MGD is also purchased from Maui Land & Pineapple Co. which diverts flows from Honokohau and Honolua Streams and exports it approximately 7 miles through transmission tunnels and ditches to the Pioneer Mill irrigation system at Mahinahina Stream. Plate 11 shows existing irrigation transmission and distribution facilities.

DOMESTIC WATER SYSTEMS

The domestic water systems, shown on Plate 12, are both publicly and privately owned. In addition to the four County systems and the Amfac system shown on Plate 12, Pioneer Mill Co. and Baldwin Packers (now Maui Land & Pineapple Co., Ltd.) developed water systems to serve their plantation villages.

Private System

The private systems utilize both surface water and high level ground water for their domestic uses. Although most of the water developed is used for irrigating the crop lands, it serves a dual purpose by providing for the domestic requirements of the plantation communities. Private systems also supply the Kaanapali resort area and supplement the County systems.

The largest private domestic water system is operated by Amfac, Inc. to serve the resort development at Kaanapali and the village of Puukolii. Water is obtained from Honokowai Tunnel and is transmitted through a recently improved system of pipelines, storage reservoirs and filter unit. To augment the source, Amfac is anticipating a production well at one of the recently completed exploratory holes in Honokowai Gulch. With the existing limited supply of high level irrigation water, Amfac needs to return this source to Pioneer Mill Co. for irrigation purposes when other sources can be provided to serve the Kaanapali resort.

Public Domestic System

The Maui County Board of Water Supply owns and operates four systems within the Lahaina District.

The domestic water system serving Lahaina town is the largest within the district. The system obtains its supply from surface water originating in Kanaha Stream and the recently completed basal water well near Lahainaluna High School. Water from Kanaha Stream is shared by the County under a three-party water rights formula with Lahainaluna High School and Pioneer Mill Company. The County

is assured of only 500,000 GPD under the formula and may purchase surplus water in excess of this quantity from Pioneer Mill Company. With the well, the County is assured of 950,000 GPD. For the fiscal year ending June, 1968, the system served 967 meters with an average consumption of 610,000 GPD.

The other three County systems, Honokowai, Alaeloa-Kahana, and Honokohau, obtain their water from a common source, the Honokohau Tunnel. This water has been made available in such quantity as may be required for the systems under an agreement with Baldwin Packers (Now Maui Land & Pineapple Co.). These systems serve a total of 193 meters with an average consumption of 174,000 GPD. The agreement with Maui Pine terminates on January 1, 1974, and there is no commitment that it will be renewed. This study assumes that new sources will be required to replace this surrendered supply.

Although the Lahaina District has become a major tourist destination area, pineapple and sugar are still the two major industries and the need for irrigating these crop lands cannot be ignored. Providing additional sources for the crop lands is not within the scope of this report, but because of the importance of agricultural need to total need, the total requirement has been examined herein. The water that has been presently developed is used primarily for irrigating the sugar cane crop land and its distribution system is shown on Plate 11 with the distribution of development water summarized on Table 3.

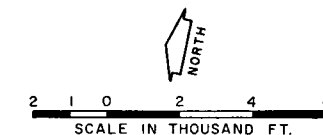
The development plan evolving from this report does not contemplate any change in use of water now being used for irrigation. In fact, it takes into account that some water (Honokohau water) may be taken from domestic application and returned to the plantation for irrigation use.



LEGEND

- IRRIGATION DITCH
- - - PIPELINE
- [3] WELL
- RESERVOIR
- BOUNDARY LINE
- - - SUBAREA BOUNDARY LINE
- TUNNELS

EXISTING IRRIGATION SYSTEM LAHAINA DISTRICT, ISLAND OF MAUI



SOURCES: 1. "PRELIMINARY REPORT ON THE WATER RESOURCES OF THE LAHAINA DISTRICT, MAUI" — CIRCULAR C-51
2. "IMPROVEMENTS TO COUNTY WATER SYSTEMS, LAHAINA DISTRICT, MAUI" — REPORT R-21
3. AMFAC INCORPORATED



TABLE 3
DISTRIBUTION OF DEVELOPED WATER FOR SUGAR CROPLAND

<u>Subarea</u> Symbol	Stream, valley or source	<u>Average annual surface water</u>		Average pumping or basal water applied	Total water applied (mgd)
		*Developed (mgd)	**Applied (mgd)		
B	Mahinahina weir	25.0	25.0		
	Honokowai	5.8	5.4		
	Kahoma	5.2	5.2		
	Kanaha	1.2	1.2		
	Kauaula	5.6	5.1		
	Launiupoko	<u>0.7</u>	<u>0.7</u>		
	Sub-total	43.5	42.6	48.4	91.0
C	Olowalu	4.8	4.8		
	Ukumehame	<u>4.2</u>	<u>4.2</u>		
	Sub-total	9.0	9.0	3.0	12.0

*Water diverted at intakes except for figure given for Mahinahina weir which represents water diverted from Honokohau and Honolua streams. Does not include 2.6 mgd diverted from Kanaha stream for domestic use.

** Water delivered to fields within the subarea. Honokowai and Kauaula sources supply domestic use.

Sources: 1. Amfac, Incorporated.
 2. "Surface Water Records of Hawaii and other Pacific Areas".
 3. "Preliminary Report on the Water Resources of the Lahaina District, Maui" -- Circular C51.

TABLE 4
DOMESTIC WATER CONSUMPTION, 1968

	<u>Avge. Daily Consumption (gpd)</u>
Honokohau	1,000
Alaeloa-Kahana	100,000
Honokowai	73,000
Kaanapali	1,200,000
Lahaina	610,000

Sources: 1. Maui County Board of Water Supply.
 2. Amfac, Incorporated.

VI ANTICIPATED WATER NEEDS

Population

Land Development Plan

Estimated Future Water
Requirement

POPULATION

Like the rest of the islands outside of Oahu, the population on Maui has declined during the past decades. In the Lahaina District, the population declined from 8,291 in 1940 to 4,844 in 1960. However the trend has changed with an increase of population to 5927 in 1967.

With the completion of several hotels and a golf course at Kaanapali, the Lahaina District has recently become a major tourist destination area. Motels, hotels and apartments built along the shores north of Kaanapali are further evidence of active development in this area.

Since the arrival of major tourist facilities in this area, the population decline has been halted. Additional tourist facilities will require support employment opportunities. This will result in a population increase. Total population of 28,500 by 1990 is estimated in the "701" planning report.

LAND DEVELOPMENT PLAN

The Maui County Planning Department has recently completed a general plan for the Lahaina District through the "701" planning study. The Land Use Plan, as shown on Plate 13, delineates the recommended land uses for the various areas. This plan provides the framework defining the extent of development of additional water facilities.

ESTIMATED FUTURE WATER REQUIREMENT

To formulate and delineate plans for the development of water sources, an estimate of future water needs would be required. Long-range estimates of water requirements are difficult to

ascertain precisely because of the many variables that have to be considered. The "701" planning study with its projection of growth to 1990 (made by Western Management Consultant, Inc.) was utilized as the basis for future domestic water requirement. The land use plan provides for the development of five community environments within the Lahaina District. The projection for the water requirement was distributed to each of these five areas to the year 2000 in increments of five years and is shown on Table 5. A land use plan is merely a guide to control the type of development within an area. It does not guarantee that actual development will follow the plan closely--either with respect to physical character or timing.

Because of the many uncertainties of regional development in its economic, financial and political areas, a plan for water resource development, or any other physical facilities program, should have two characteristics; (a) the ability to be developed incrementally as need arises, and (b) the capability for modification as needs change. The alternatives of development set forth in the recommended program herein possess these characteristics and thus promote orderly, timely, and flexible development.

The estimated water requirement for the population centers in the district is based on an average annual unit consumption of 150 GPD with a density of 4.0 person per residential or apartment unit. The requirement of 550 GPD per room for the hotels was based on the average annual consumption experienced by the hotels at Kaanapali. During the dry season, with the additional water required for lawn

irrigation, the unit demand may increase to an additional 50 per-cent of the average demand of 900 GPD per unit for the residential-apartments and 825 GPD per room for the hotels.

Amfac, Inc. is anticipating a faster rate of growth for its Kaanapali resort development than is shown in the estimated water demand table (Table 5) which is based on the "701" plan. In its recent developments, the unit demand for the apartment-residential units shows 25 per cent greater than commonly estimated consumption rates. Its estimate of water requirement for the year 1980 is indicated in a footnote on the estimated water demand table and is shown on the supply-demand relationship (Plates 21 & 25).

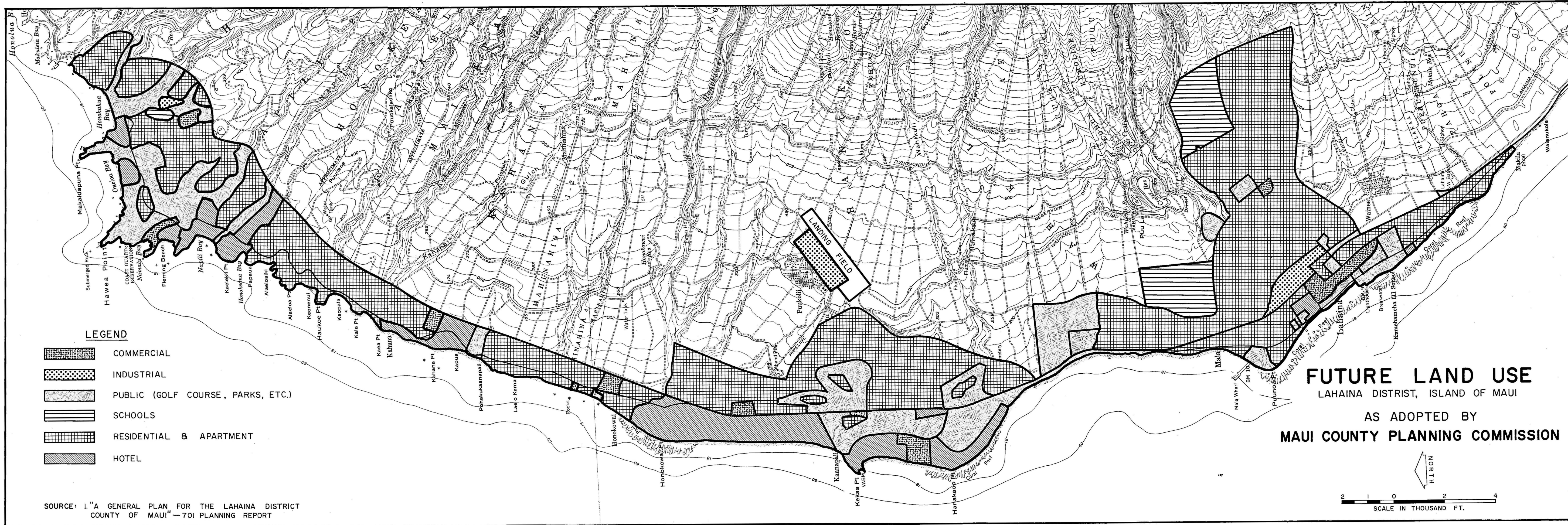


TABLE 5
ESTIMATED WATER DEMAND FOR LAHAINA DISTRICT

Water Service Area	Water Use	Unit	Average Annual Unit Demand (Gal. /Day)	1968 Consumption (mgd)	***1970 Demand (mgd)	1975		1980****		1985		1990		1995		2000	
						Size	Demand (mgd)	Size	Demand (mgd)	Size	Demand (mgd)	Size	Demand (mgd)	Size	Demand (mgd)	Size	Demand (mgd)
<u>Lahaina</u>	Res. -Apts.	Units	600/Unit			1800	1.08	2700	1.62	3460	2.08	4270	2.56	5000	3.00	5600	3.36
	Hotel	Rooms	550/Room			300	0.17	500	0.28	500	0.28	500	0.28	500	0.28	500	0.28
	Commercial	Acres	5000/Acre			16	0.08	21	0.11	26	0.13	30	0.15	30	0.15	30	0.15
	Industrial	Acres	4000/Acre			10	0.04	15	0.06	15	0.06	15	0.06	20	0.08	20	0.08
	Public	Acres	4000/Acre			55	0.22	80	0.32	100	0.40	130	0.52	150	0.60	150	0.60
	Schools	Acres	2000/Acre			50	<u>0.10</u>	80	<u>0.16</u>	110	<u>0.22</u>	130	<u>0.26</u>	160	<u>0.32</u>	160	<u>0.32</u>
Sub-Total				0.61	0.70		<u>1.69</u>		<u>2.55</u>		<u>3.17</u>		<u>3.83</u>		<u>4.43</u>		<u>4.79</u>
<u>Kaanapali</u>	Res. -Apts.	Units	600/Unit			800	0.48	1200	0.72	1540	0.92	1900	1.14	2100	1.26	2500	1.50
	Hotel	Rooms	550/Room			3150	1.73	4000	2.20	4800	2.64	5600	3.08	6400	3.52	7000	3.85
	Commercial	Acres	5000/Acre			7	0.04	9	0.05	11	0.06	13	0.07	15	0.08	15	0.08
	Industrial	Acres	4000/Acre			5	0.02	10	0.04	10	0.04	10	0.04	15	0.06	15	0.06
	*Public	Acres	4000/Acre			292	<u>(1.17)</u>	292	<u>(1.17)</u>	292	<u>(1.17)</u>	292	<u>(1.17)</u>	292	<u>(1.17)</u>	292	<u>(1.17)</u>
Sub-Total				1.20	1.30		<u>2.27</u>		<u>3.01</u>		<u>3.66</u>		<u>4.33</u>		<u>4.92</u>		<u>5.49</u>
<u>Honokowai</u>	Res. -Apts.	Units	600/Unit			280	0.17	420	0.25	540	0.32	670	0.40	800	0.48	900	0.54
	Commercial	Acres	5000/Acre			3	0.02	3	0.02	4	0.02	5	0.03	5	0.03	5	0.03
	Public	Acres	4000/Acre			5	<u>0.02</u>	5	<u>0.02</u>	5	<u>0.02</u>	5	<u>0.02</u>	5	<u>0.02</u>	5	<u>0.02</u>
Sub-Total				0.07	0.10		<u>0.21</u>		<u>0.29</u>		<u>0.36</u>		<u>0.45</u>		<u>0.53</u>		<u>0.59</u>
<u>Kahana</u>	Res. -Apts.	Units	600/Unit			440	0.26	660	0.40	850	0.51	1050	0.63	1250	0.75	1450	0.87
	Hotel	Rooms	550/Room			250	0.14	350	0.19	650	0.36	900	0.50	1100	0.61	1200	0.66
	Commercial	Acres	5000/Acre			1	0.01	3	0.02	4	0.02	4	0.02	4	0.02	4	0.02
	Public	Acres	4000/Acre			9	<u>0.04</u>	9	<u>0.04</u>	18	<u>0.07</u>	18	<u>0.07</u>	18	<u>0.07</u>	18	<u>0.07</u>
Sub-Total					0.20		<u>0.45</u>		<u>0.65</u>		<u>0.96</u>		<u>1.22</u>		<u>1.45</u>		<u>1.68</u>
<u>Kapalua</u>	Res. -Apts.	Units	600/Unit			680	0.41	1020	0.61	1310	0.79	1610	0.97	1800	1.08	2000	1.20
	Hotel	Rooms	550/Room			300	0.17	550	0.30	1050	0.58	1500	0.83	1700	0.94	1900	0.05
	Commercial	Acres	5000/Acre			3	0.02	4	0.02	5	0.02	7	0.04	7	0.04	7	0.04
	Industrial	Acres	4000/Acre			5	0.02	5	0.02	5	0.03	5	0.02	7	0.03	7	0.03
	Public	Acres	4000/Acre			10	0.04	10	0.04	28	0.11	28	0.11	28	0.11	28	0.11
	Schools	Acres	2000/Acre	**0.30	0.40	9	<u>0.02</u>	9	<u>0.02</u>	9	<u>0.02</u>	9	<u>0.02</u>	9	<u>0.02</u>	9	<u>0.02</u>
							<u>0.68</u>		<u>1.01</u>		<u>1.55</u>		<u>1.99</u>		<u>2.22</u>		<u>2.45</u>
TOTAL				<u>2.18</u>	<u>2.70</u>		<u>5.30</u>		<u>7.51</u>		<u>9.70</u>		<u>11.82</u>		<u>13.55</u>		<u>14.94</u>

*Demand for irrigating public areas not included at Kaanapali.

Amfac utilizing brackish basal ground water and reclaimed water for golf course irrigation.

**Estimated consumption for Kahana and Kapalua.

***Estimate for 1970 based on present use.

****Amfac, Inc. estimate for 1980 is 2.76 mgd for the Lahaina area and 4.66 for Kaanapali.

VII PROSPECTS FOR WATER DEVELOPMENT

General

Surface Runoff

Desalinization

Waste Water Recovery

Ground Water

The Water Budget

GENERAL

The primary source of all important water supply in the Hawaiian Islands is the sea. Through the action of the trade or Kona winds moving against the Hawaiian mountain masses, moisture laden air is lifted, cooled, condensed and falls in the form of rain. Being surrounded by the sea, the primary source for the islands is unlimited, but the solar energy that creates winds and causes evaporation is an item of highly variable input. Thus, the end product, rain, is a highly variable commodity.

Once water is delivered to the approximate area of need, the problem becomes simply the capture or recovery of the supply and its application to beneficial use. A solution which is simple in concept but extremely complex in application. The factors are many and most of them are variable, giving rise to numerous answers rather than one single, finite value. Thus, the actual physical system developed must be well within the envelope representing the most favorable pattern of water available.

The basic categories of water sources for the development program are:

- a. Rainfall runoff (surface stream runoff less stream base flow)
- b. Ground water supplies derived from the infiltration of rainfall and surface runoff into the ground.
- c. Desalinized ocean water.
- d. Reclaimed waste water.
- e. Any combination of the aforementioned.

SURFACE RUNOFF

Data reviewed and collated in this study leads to the conclusion that the development and utilization of surface runoff is not a significant source of water to meet the needs of the Lahaina District.

The reasons for this conclusion are simple:

a. Most of the rainfall runoff and base flow is being exploited by intake and diversionary structures. The larger portion is used for agricultural purposes which will continue in effect, although any increase in total agricultural use will not be significant.

b. The residual rainfall and base flow water now escaping to the sea is not sufficiently large in amount to justify the high cost of its development.

The quickest means of evaluating the extent of rainfall runoff available is to compare the past diversion level with the discharge duration of the streams in question. An excellent example is presented by Honokohau Stream, which is thought by some to be a good subject for further surface water development.

An examination of the Honokohau Duration-Discharge Curve (Plate 15) will show flow to be below 65 MGD 95 per cent of the time. The diversion capacity of the Honokohau tunnel and ditch approximates 65 MGD, which is adequate to take care of the available flow 95 per cent of the time. The flow above 65 MGD occurs only 5 per cent of the time, requiring excessive development in dams or in diversion, transmission and storage facilities to capture the water.

This problem is further explained by examining the available matching data for stream flow and diversion. Comparison in values

is shown in Appendix 2 & 3. For 1968, 100 per cent utilization of all stream flow would have increased the Honokohau system yield by an average of about 6 MGD. To utilize the 6 MGD it would be necessary to store or divert and store all the water developed above the gaging station.

To develop all the water between November 1, 1967 and May 1, 1968, in stream storage, would require 1203 MG of storage because practically all of the water comes in peak flow periods, for example 248 MG in a two-day period.

Storage in stream at Honokohau would be very expensive for the following reasons:

- a. Inaccessibility of site.
- b. Need for expensive spillway facilities for once in 50-year storm flow.
- c. Site working restrictions.
- d. Need for extensive and expensive reservoir grouting to prevent leakage.

The possibility of the development of base flow water downstream of the Honokohau Stream diversion is placed low on priority of development. The reasons are as follows:

- a. Data is limited with a "best guess" of 1.8 MGD of water available in total.
- b. The years in which base flows were observed approximate median flow years and these might represent an optimistic value.

c. Part or perhaps all of the base flow below the intake is required to meet the needs of taro farms.

d. Extensive transmission facilities would be required to deliver to the service areas of future need.

e. Adequate power supplies for pumping would be expensive to provide.

f. Land acquisition might be a problem.

Expansion of diversion capacity would also be expensive and difficult to coordinate with the need for continuing use of the transmission.

The limitation is even more effectively illustrated when the supply characteristic of the year 1968 is placed in the relative yield picture. Evaluation of 1968 in comparison with other streams having similar trends shows 1968 to be about the same as a median monthly year condition. Therefore the potentially developable supply from surplus surface sources on Honokohau would be less than the 6 MGD values in 50 per cent of the years.

The developable supply for a critical water year is the basis of evaluation for a domestic supply system. The most critical supply year varies from stream to stream and from gage location to gage location. 1945 was a year of critical supply at the Honokohau gage. Full capture of yield and application to use, assuming 100 per cent level, would have provided an increase in supply of about 2 MGD for 1945--an amount hardly justified in view of the development costs involved.

Honolua, Honokahua, Kahana, Honokowai, Kahoma, Kanaha, all long narrow valleys in the northern part of the district-inhibit, within evaluation of the limited data available, demonstrate the same trend.

The resources of Olowalu and Ukumehame streams are slightly in excess of the needs of their immediate area, the eastern portion of the Lahaina District, but are not sufficiently large to justify transport area of future use, the excess being only on the order of 3 MGD practically all being peak rainfall runoff.

Additional problems mitigate against the development of additional surface water. They are:

- a. Water quality problems in heavy rain periods.
- b. Algae problems in open storage reservoirs.

No recent study or evaluation of water sources in West Maui has ever seriously suggested development of additional surface water to meet future needs. This study reinforces that position.

DESALINIZATION

The desalinization of sea water holds little hope as a solution to Lahaina District water supply problems because of the costs involved. Effective costs in desalinization are a result of maximization of energy conservation and low energy costs factors not likely to be operational in the Lahaina District area for some time to come.

This subject is covered in more detail in the Appendix to this report.

WASTE WATER RECOVERY

Recovery of industrial and domestic liquid wastes, their treatment and purification have developed a new technique for the conservation, through reuse, of water resources. The first requirement for a program of this kind is a collection system which will pick up the waste material and transport it at a reasonable cost to the point of reprocessing.

Amfac, Inc. is now reclaiming liquid effluent from its domestic sewage treatment facilities for use as irrigation waste. Regular secondary treatment is sufficient in this case to produce acceptable irrigation water.

There are places such as Windhoek, South West Africa, where the technique is much more refined and the end result of the treatment of domestic sewage is of a potable quality water supply.

Recent experimental and operational experience indicates that advanced physical-chemical treatment of secondary treatment of final effluent or even primary clarified waste can be accomplished to produce potable water at approximately \$0.25 and \$0.30 per 1000 gallons respectively.

The type and cost of waste water treatment are highly varied because of the diffuse character of the waste waters. The primary problem in the adoption of this technique is a psychological one, dealing with the "minds eye" relationship between sewage and drinking water. The process does offer the possibility of substituting reclaimed water for potable quality water used for purposes not requiring potable standard.

The program could be expanded as urban growth occurs and wastes are more easily concentrated throughout the area.

Costs to reach the potable water quality level are not competitive with other development possibilities.

GROUND WATER

The final source for water development is ground water--either basal or high level (elevated) dike water. Because of the inter-relationship of basal and high level dike water, they will be covered jointly in the following discussion of the water budget.

Both ground water categories are potential sources of supply for the expanding needs of Lahaina District as the water budget discussion will disclose.

THE WATER BUDGET

The conclusions, recommendations and development plan that arise out of this study result, in large measure, from the resources picture unfolded from the Water Budget Analysis. The "Budget" is an accounting of the disposition of rainfall on the lands of the Lahaina District.

Basic data required to develop the "Budget" is diverse and extensive. Information must include, but is not limited to, the following major areas:

- a. Amount and distribution of rainfall on the land.
- b. The extent and pattern of runoff directly to the ocean.
- c. The rate and extent of infiltration into the ground water aquifers.

d. The porosity, permeability, and transmissibility of the aquifers.

e. The degree of evaporation and vegetal transpiration.

f. The diversion, application and use of surface water.

g. The extraction and use of ground water.

h. Other parameters.

Most of these factors vary in time and in location, resulting in infinitely complex sets of situations. Many of the factors are inexactly known if known at all. Nonetheless the "Budget" is the best device for the establishment of overall order-of-magnitude values. When assumptions used and conclusions drawn are conservative yet leave potential to exploit existing resources to meet needs the development program derived is meaningful, though not necessarily specific, as will be shown later.

Since the end result of the Budget Analysis is to determine the amount of exploitation of ground water that can take place and, since ground water supplies can provide storage to draw from in rain deficient periods, a median month analysis was employed in the study. To further relate resource availability to needs, the years were analyzed in two parts--April to October and November to March. The Lahaina District was broken into three areas coinciding with the U.S.G.S. subdivisions A, B, and C of their report entitled PRELIMINARY REPORT ON THE WATER RESOURCES OF THE LAHAINA DISTRICT and illustrated in Appendix 1.

In the water budget evaluation, there is a significant difference between areas A and B. Water is imported to area B from area A.

Mechanics of the "Budget":

The "Budget" is a variable itself in that it may be evaluated for a dry period, a wet period, a median water year, an average water year or a number of the alternatives.

Plate No. 17 is a summary compilation for the water budget for each of the subdivisions. The water budget is developed as follows:

- a. The rainfall for two rainfall periods, April through October and November through March, is developed from the isohyetal map as a summation of monthly median rainfall for the areas above and below the approximate line dividing basal water from high level dike water.
- b. The evapo-transpiration for both upper and lower areas is computed.
- c. The evapo-transpiration values are subtracted from the gross rainfall values to give a net effective rainfall figure.
- d. From stream gaging records or correlations of stream gaging, a value for the amount of runoff to the sea is calculated.
- e. The amount of surface water diverted from the basin is taken from records and added to the direct-to-sea runoff.
- f. The sum of direct runoff to the sea and out-of-basin diversion is deducted from the effective rainfall, leaving a value called "natural rainfall surplus".

g. The water directed to consumptive use or diverted out-of-basin is deducted from the "natural rainfall surplus", leaving a value called "surplus ground water flux", which is the net amount of water available to recharge the aquifer for the sub-area under level basal water recharge.)

Area A:

Reference to Plate 17 will show that the surplus water available for recharge of depleted ground water aquifers averages 12 MGD during a median month year situation for the upper portion of Area A. The same table shows that the surplus available for basal ground water recharge for Area A lower portion totals 17 MGD on the average month. The sum total of water available for the recharge of the ground water aquifers of Area A is approximately 29 MGD.

The entire 29 MGD cannot be taken for use in the Lahaina District. The reasons for this are two-fold. First, this figure is based on a median monthly value, which means in effect that 50 per cent of the time the amount of water going to ground water recharge would be less than the 29 MGD. Limited correlative studies (based on data available) indicate that the ground water contribution during a dry weather cycle would be of an order of magnitude of one-third the median year value. Secondly, a large portion of the flow to ground water is required merely to maintain the fresh water integrity of the basal water lens. This report identifies this quantity of water as the "water balance flow." Where large quantities of water

are migrating from the mountain areas to the sea coast via ground water passages, resistance to the higher flow values tends to raise the lens level (the ultimate in this application is a cap-rock that totally restricts flow). Where this condition prevails, a higher quality water can be obtained from the basal supply. In other words, the quality of water obtainable from the basal lens is a function of hydraulic gradient, and more so when the underground conditions are conducive to a more rapid flow-through rate in the ground water reservoir.

Area B:

The same basic approach has been applied to Area B by personnel of Amfac. These evaluations differ from that applied to Area A, only in that additional complexities are introduced by the import of water into the low level of Area B from Area A; which is required by Area B's net deficiency of water to meet consumptive requirements. Even during the winter period, November through March, the gross consumptive requirements of evapo-transpiration of the lower portion of Area B exceed the water dropping on the area in the form of rain.

Taking into account import to the area, extraction of water from the basal aquifer, the infiltration of imported water and reinfiltration of pumped basal water, the net consumptive losses related to domestic and industrial uses, a surplus of about 35 MGD for Area B is obtained. As pointed out, a substantial portion of this water would not be available for exploitation because of the requirement to maintain the ground water quality balance flow.

Area C:

Because of data limitation, Area C is less susceptible to analysis than Areas A or B. Data is sufficient to provide adequate order-of-magnitude values on which scope and priority of water development can be based.

Again working from a monthly median rainfall basis, we find total annual resources to approximate 40 MGD. Evapo-transpiration of natural cover and agricultural needs total about 22 MGD.

About 9 MGD is required from stream diversion of upper area runoff to supplement deficient resources for the lower area. The existing diversionary facilities represent the probable limit of economic rainfall and base flow runoff development.

The residual surplus ground and surface water of approximately 6 MGD for a median year condition would be substantially reduced in critical water years to very low levels and would be essential as a ground water recharge component to maintain the aquifer water quality balance.

Minimum recorded flows for Olowalu and Ukumehame division are substantially 3 MGD below the average diversion 9 MGD which represents the normal need.

Examination of chloride content of water development shaft in Area C will show the chloride concentration markedly responsive to shaft water level and thus highly dependent on ground water recharge.

Future development of major water supplies in Area C is very doubtful.



LEGEND

- PERENNIAL STREAM
- - - - - INTERMITTENT STREAM
- TRANSMISSION TUNNEL
- △ I-22M MISCELLANEOUS STREAM GAGING STATION
- ▲ I-1 ACTIVE STREAM GAGING STATION
- Y STREAM DIVERSION

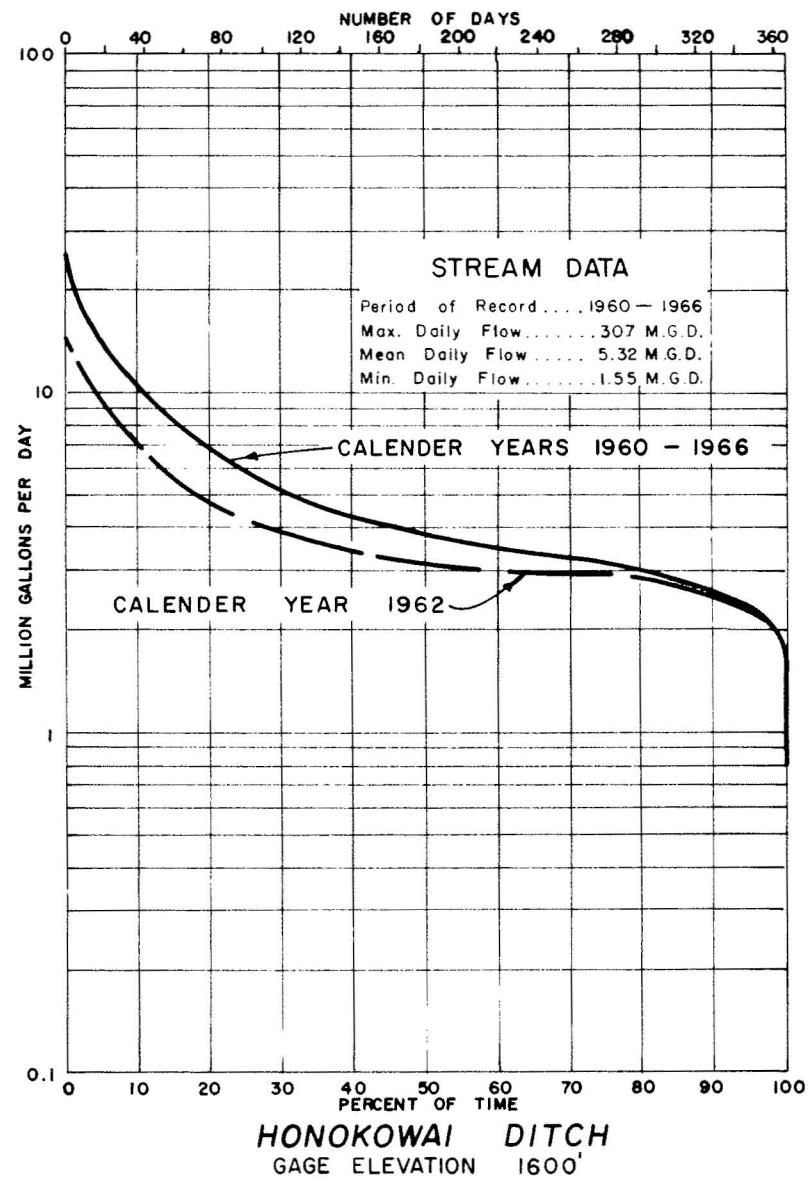
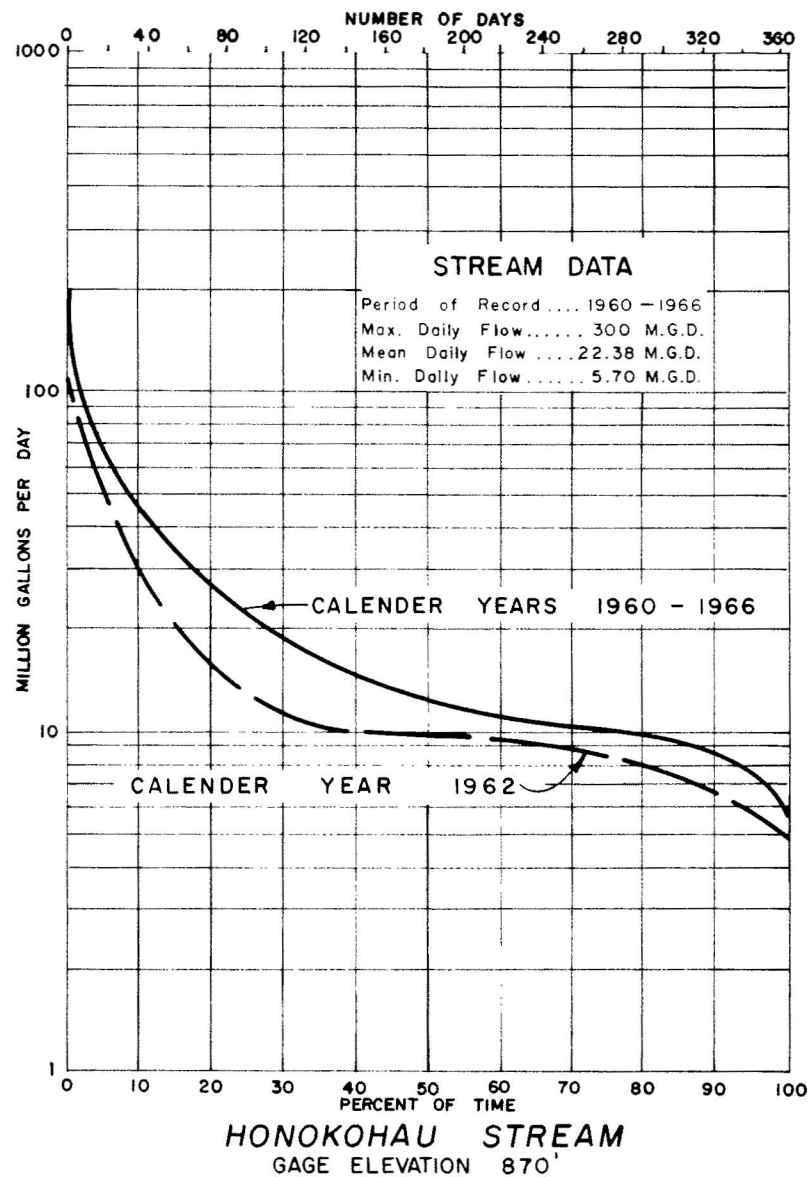
MAJOR STREAMS AND TRANSMISSION TUNNELS

LAHAINA DISTRICT, ISLAND OF MAUI



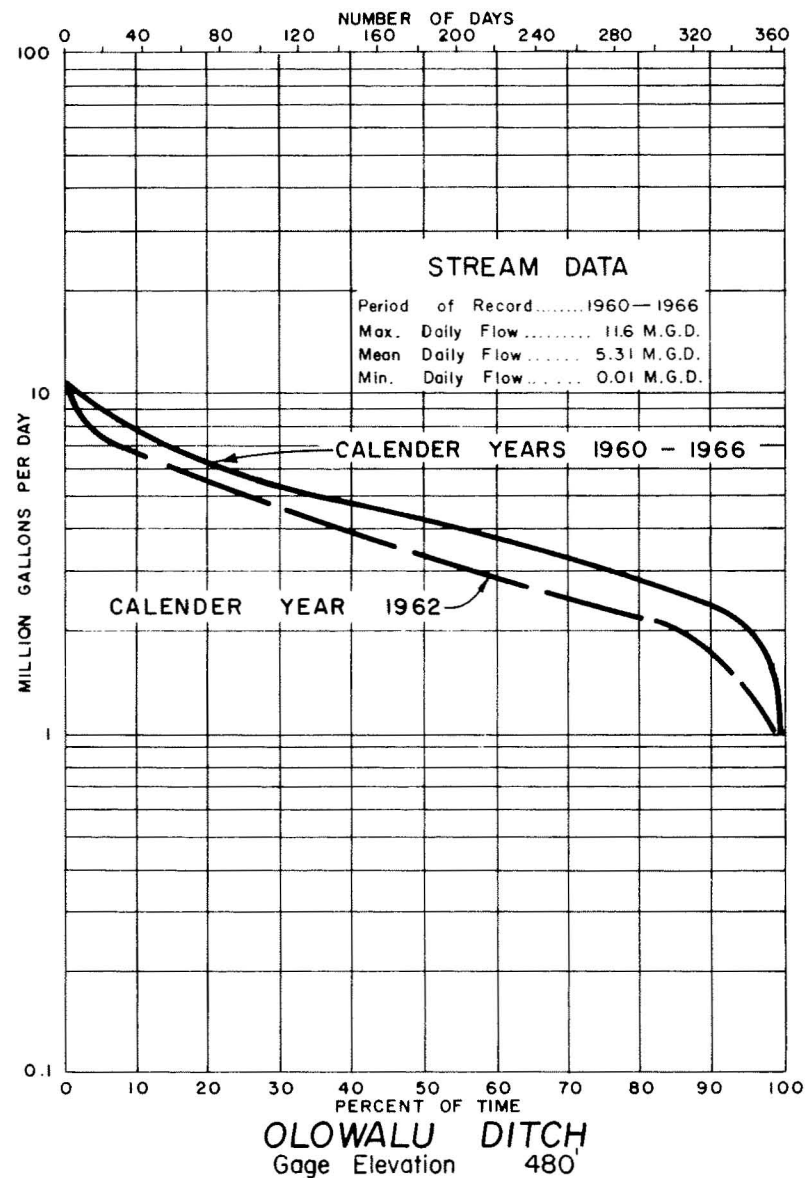
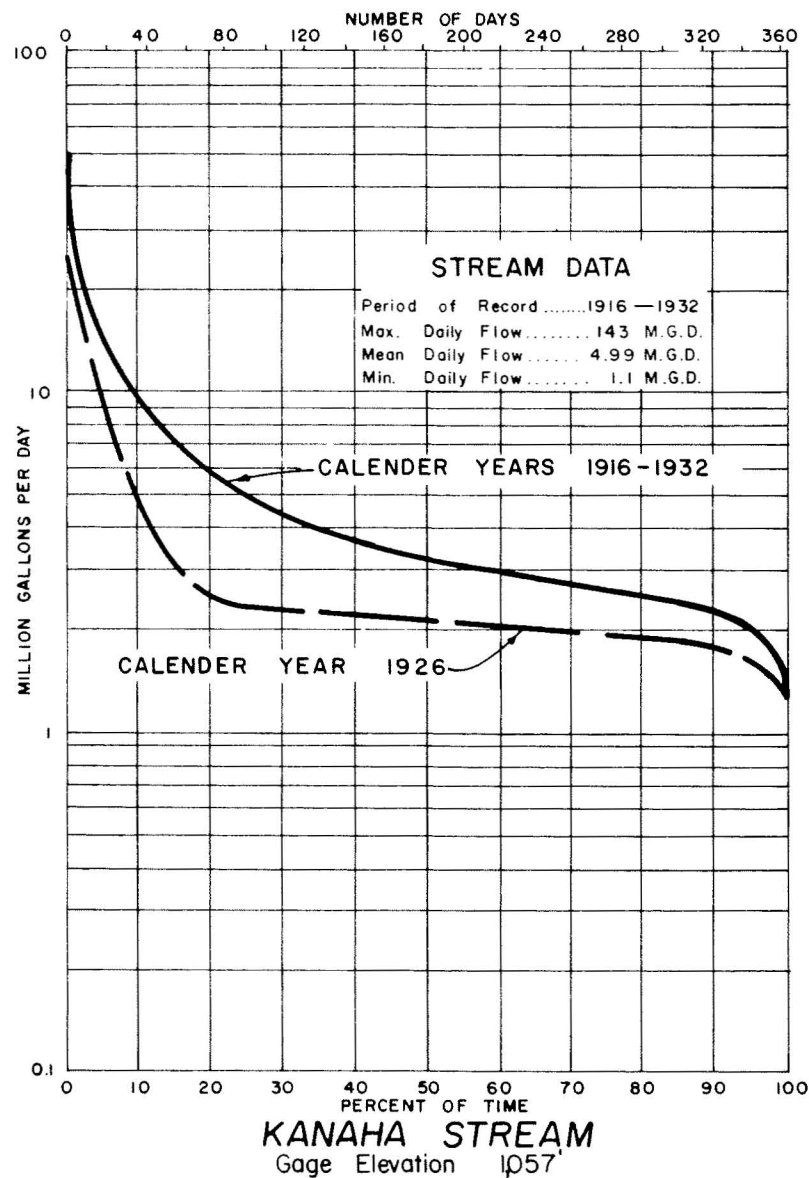
2 1 0 2 4 6
SCALE IN THOUSAND FT.

SOURCE: I. IMPROVEMENTS TO COUNTY WATER SYSTEMS, LAHAINA DISTRICT,
MAUI — REPORT R-21



DURATION-DISCHARGE CURVES

SOURCE: 1. "SURFACE WATER RECORDS OF HAWAII AND OTHER PACIFIC AREAS"



DURATION - DISCHARGE CURVES

SOURCES: 1. "SURFACE WATER RECORDS OF HAWAII AND OTHER PACIFIC AREAS"
2. "IMPROVEMENTS TO COUNTY WATER SYSTEMS, LAHAINA DISTRICT, MAUI" — REPORT R-21

TABLE 6
FLOW DATA - MAJOR STREAMS IN LAHAINA DISTRICT

Stream	Altitudes of diversion (ft.)	Drainage area above intake (sq. mi.)	Average Annual Rainfall (MGD)	<u>Discharge (MGD)</u>	
				Average flow (estimated)	Average diverted
Honokohau	870	4.3	49.8	30	25.0
Honolua	870	1.8	11.8	5	2.8
Honokowai				8	5.8
Amalu	1,580	1.0	8.6		
Kapaloa	1,550	1.1	12.2		
Kahoma	1,930	1.5	14.4	7	5.2
Kanaha	1,140	1.6	7.5	5	2.6
Kauaula	1,530	1.9	9.1	7	5.6
Launiupoko	1,280	1.2	3.7	1	0.7
Olowalu	540	3.4	32.0	6	4.8
Ukumehame	240	4.1	19.2	6	4.2
Total (rounded)		22	168	75	57

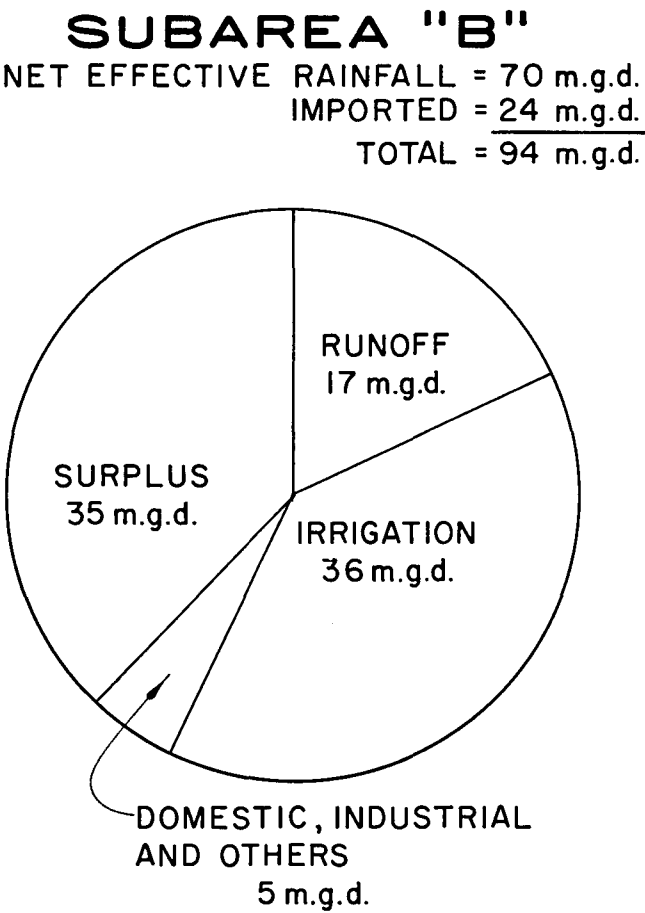
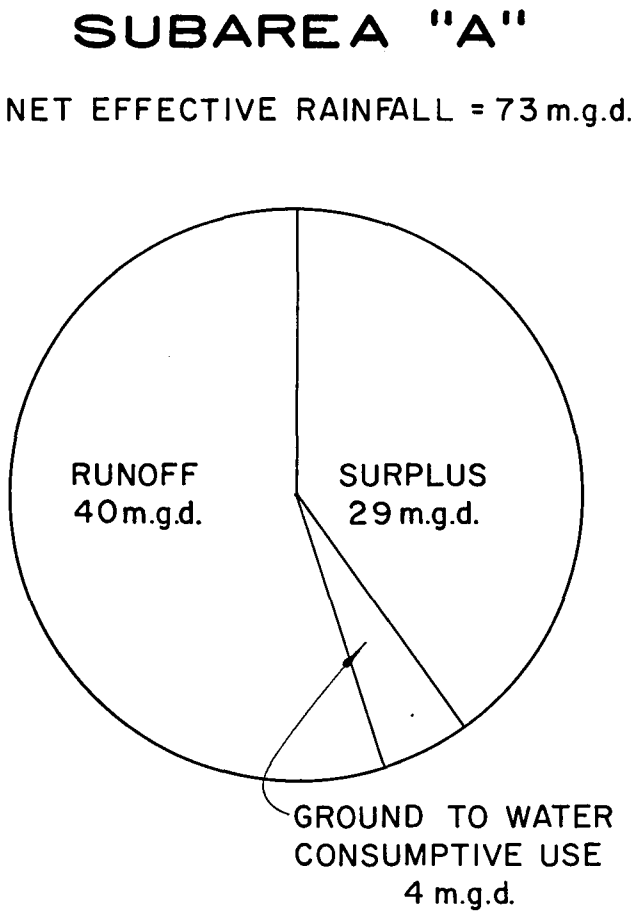
- Source: 1. "Report on the Water Resources of the Lahaina District, Maui" -- Circular C51.
2. Amfac, Incorporated.
3. "Surface Water Records of Hawaii and other Pacific Areas".

SUBAREA "A"							
HIGH LEVEL	GROSS RAINFALL	EVAPOTRANS-PIRATION	NET EFF. RAINFALL	RUNOFF	NATURAL RAINFALL SURPLUS	GROUND TO WATER CON-SUMPTIVE USE	SURPLUS
APR. - OCT.	13,600	3,800	9,800	7,100	2,700	—	—
NOV. - MAR.	11,100	1,300	9,900	6,900	3,000	—	—
TOTALS	24,700	5,100	19,700	14,000	5,700	—	—
M.G.D.	68	14	54	38	16	4	12
BASAL							
APR. - OCT.	10,500	6,200	4,300	400	3,900	—	—
NOV. - MAR.	9,100	6,400	2,600	300	2,300	—	—
TOTALS	19,600	12,600	6,900	700	6,200	—	—
M.G.D.	54	35	19	2	17	—	17

NOTE: RUNOFF FOR BASAL AREA IS ASSUMED TO BE 10% OF NET EFFECTIVE RAINFALL.

SUBAREA "C"							
APR. - OCT.	7,000	—	2,000	—	—	—	—
NOV. - MAR.	7,700	—	3,600	—	—	—	—
TOTALS	14,700	—	5,600	—	—	—	—
M.G.D.	40	22 ⁽²⁾	15	9 ⁽¹⁾	6	—	6

NOTE: 1. FLOOD RUNOFF DEVELOPED FOR CONSUMPTIVE USE OF SUGAR CROPLAND.
2. INCLUDE 9m.g.d. FOR CONSUMPTIVE USE OF SUGAR CROPLAND.



NOTE: SUBAREA "B" WATER BUDGET DATA OBTAINED FROM AMFAC INC.



SOURCE : I. AMFAC INCORPORATED

VIII WATER RIGHTS

Kanaha Stream

Honokohau Tunnel

KANAHA STREAM

The State of Hawaii (then Territory of Hawaii) and Pioneer Mill Company entered into an agreement in October, 1904, for the use of the water from Kanaha Stream. Under the agreement, Lahainaluna High School would have continuous and uninterrupted use of the water for a period of four and one-half (4-1/2) hours each day. Pioneer Mill Company and kuleana owners below the school then would have use of the water during the remainder of the day.

In July, 1906, and modified in July, 1912, Pioneer Mill Company, for a purchase price of \$30,000, conveyed to the Territory and its political subdivision, the County of Maui, perpetual rights to 500,000 GPD from Kanaha Stream. The County, by a separate agreement, may also purchase water in excess of the allocated 500,000 gallons daily at a rate of \$0.05 per thousand gallons from Pioneer Mill Company. Pioneer Mill Company has use of the remainder of the water after requirements of the school and County are satisfied. The maintenance of the facilities is shared by three parties.

HONOKOHAU TUNNEL

Bladwin Packers (Maui Land & Pineapple Co.) entered into an agreement with the Maui County Waterworks Board, effective January 1, 1954, for twenty years, for the delivery of potable water to the Honokohau Valley pipeline, the Alaeloa water system, and the Honokowai water system, for \$50.00 per million gallons. This agreement may be terminated at the end of any calendar year by notice

in writing given by the party so desiring to terminate to the other not less than three months prior to date of the desired termination.

Baldwin Packers also entered into an agreement with Pioneer Mill Company, Ltd., effective June 1, 1960, for twenty years and seven months and for such further period as Pioneer Mill continues to cultivate cane as Lessee of Baldwin Packers, to sell a portion of the flow from the Honokohau Ditch System as stipulated below:

The quantity of water sold shall be in excess of the flow necessary to satisfy the water rights of others, water deliveries to the County of Maui and the Kaanapali Beach Resort Development, or other such higher and better water usage, possible delivery of water to the cannery of Baldwin Packers, and other needs of Baldwin Packers not exceeding two (2) million gallons in a single calendar day, in addition to said cannery needs.

IX WATER DEVELOPMENT PLAN

General

Development Plan

Staged Development

GENERAL

To make possible the potential growth of the Lahaina District, new sources of water to augment the present supplies will be necessary.

As discussed earlier, undeveloped ground water, although limited in quantity, awaits development and would be the most practical source of water. It is necessary then to formulate a plan to best develop these sources and transfer them to the service areas.

In studying the various means whereby these ground waters could be successfully developed, several alternatives were considered. Discussed briefly are the alternatives considered:

Vertical Wells

This scheme consists of providing vertical wells to the basal lens or into the dike compartments. The water then is brought to the surface with deepwell turbine-type pumps.

Maui-Type Wells

Maui-type well is a name applied to a mine-like shaft to the basal water lens with one or more infiltration tunnels skimming the fresh water. As with the vertical wells, water has to be brought to the surface by pumping.

Lanai-Type Wells

The principle of the Lanai-type well is to develop high level ground water from behind faults and dike barriers, either by shafts and tunnels or by drilled wells, or by a combination of them. Again pumping is required for this alternative.

Water Development Tunnel

High level ground water can also be developed by driving horizontal tunnels into the dike structures. The water developed then would be delivered to the tunnel portal by gravity, thus eliminating any pumping.

DEVELOPMENT PLAN

After evaluating the above alternatives, it is recommended that vertical wells be the choice for the development of additional water for the Lahaina District. The development tunnel alternative would be the economic choice in terms of annual cost for the construction, maintenance and operation if full utilization of ultimate supply were possible. This is not compatible with the projected growth pattern of demands. The uncertainty of the potential yield from the source and the rate of growth of the area mitigate against recommending major development with a tunnel. Vertical wells can be developed in stages as the demand arises in each of the service areas.

Two recommended plans for the development of the ground water supplies are shown. One of the plans proposes development of high level ground water and the other plan proposes development of basal water. If found successful, the high level ground water would be the more favorable. It will produce a better quality of water and would save on pumping costs, and the water would never go brackish no matter how heavily the well is pumped.

Amfac, Inc. has recently completed exploring the Honokowai Gulch, and dike water has been found in a number of the exploratory holes at various elevations. With a growing domestic demand

for its resort area, Amfac, Inc. is anticipating development of a production well at one of their test hole sites. Water from this well would be pumped into the Honokowai Tunnel and transmitted through their system. It was indicated that when and if other sources could be made available for its Kaanapali resort development, this system will be turned over to Pioneer Mill Company for irrigation use.

The State is planning to explore for high level dike water in Kanaha Stream above Lahainaluna High School and in the northern part of the district in Honolua and Honokahua streams. The anticipated increase in the future water needs of the Lahaina District would be made by the stage development of the wells in Honokowai Gulch and in the areas in which the State plans to explore.

As shown on the supply-demand relationship for the four service areas (Plates 20 to 27), the demand would be met by utilizing the existing Lahaina source, the proposed wells at Honokowai Gulch recently explored by Amfac, Inc., and the development of the various wells where the State is planning to explore for high level dike water.

Presently the Maui Board of Water Supply has an agreement to purchase water from Maui Land & Pineapple Company as required for domestic use to serve Honokowai, Alaeloa-Kahana and Honokohau systems. This agreement expires in 1974 but in arriving at this development plan it is assumed that the agreement may not be renewed.

Until pumping tests are made, the yield from the proposed wells would be uncertain, but it is believed that adequate quantities

of potable water are available to insure a continued growth for the area and will be able to meet the anticipated average annual demand to the year 2000. For further growth of the area, additional sources must be developed from either Honokohau Valley or beyond.

The supply to the service areas would be limited to the yield from these sources and the facilities provided under this development plan are based on the estimated yield from each of these sources.

As previously mentioned, Amfac, Inc. presently operates its own water system for its resort development. This development plan is based on the eventual consolidation of the public and private domestic water systems into one integrated system for the transmission, storage and distribution of the water to the service areas.

Facilities Criteria

Anticipated water requirements for the Lahaina District area should be met by a staged development of wells along with the construction of necessary transmission and storage facilities.

The water developed from the wells would be brought to the surface by deepwell turbine pumps and transmitted through the lines into concrete storage tanks. The pumps would not be operating continuously throughout the day and should be sized, together with the transmission facilities, to provide for peak daily demands of 1.5 times the average daily demand. The pumps would be controlled by the water level controls within the storage tanks, shutting the pumps off

at the full position of the reservoir and starting them as required with drop in reservoir level.

The storage facilities to be provided would serve as a fire reserve and also as a domestic reserve during unusual heavy draft or other emergencies such as power failure and break in mains. The requirement or criteria for fire demand and reserve is determined in part by the Fire Rating Bureau for which any development's insurance is set by the extent of fire protection provided for the development. The requirement for fire fighting capacity is based on many factors such as water source, fire fighting equipment, size of development, and type of development.

The criteria for fire reserve was based on population to be served for a residential development as recommended by the National Board of Fire Underwriters with a minimum reserve of 1.8 million gallons for resort-residential development. For a large development, it would be unusual for the maximum draft to coincide with a serious fire. Therefore, the storage tanks are sized on the basis of fire demand during average domestic demand with the sources providing for peak flow.

STAGED DEVELOPMENT

The sources, together with the transmission and storage facilities, would be developed in stages as the demand requires. As previously mentioned, prior to developing the sources, each of the areas would have to be investigated and explored by test wells. The final plan selected consists of the development of either high level ground water or basal water in stages, as follows:

High Level Ground Water

Stage I: This stage starts operating in or about 1971 and consists of the following elements to provide for Lahaina service area.

- a. Kanaha Well No. 1 at Elevation 1000 with 1.5 MGD pump.
- b. 1,000 feet of 12-inch diameter cast iron connecting pipeline.
- c. One 0.5 MG tank.

Stage II: This stage starts operating in or about 1972 and consists of the following elements to provide for Kaanapali service area.

- a. Honokowai Well T-6 at Elevation 800 with 1.50 MGD pump.
- b. 5,000 feet of 12-inch and 7,500 feet of 16-inch diameter cast iron connecting pipeline.

Stage III: This stage starts operating in or about 1973 and consists of the following elements to provide for Honokowai, Kahana and Kapalua service areas.

- a. Honokahua Wells No. 1 and No. 2 at Elevations 1200 and 1400 with 1.80 MGD pumps.
- b. 1,500 feet of 8-inch, 5,000 feet of 10-inch, 6,000 feet of 12-inch and 9,000 feet of 16-inch diameter cast iron connecting pipeline.
- c. One 2.0 MG tank.

Stage IV: This stage starts operating in or about 1974 and consists of the following elements to provide for Kaanapali service area.

- a. Honokowai Well 6-A at Elevation 1,000 with 1.50 MGD pump.
- b. 2,000 feet of 10-inch diameter cast iron connecting pipeline.

Stage V: This stage starts operating in or about 1976 and consists of the following elements to provide for Lahaina and Kaa-
napali service areas.

- a. Kanaha Well No. 2 at Elevation 1200 with 1.50 MGD pump.
- b. Honokowai Well T-7 at Elevation 1200 with 1.50 MGD pump.
- c. 7,000 feet of 8-inch diameter cast iron connecting pipeline.
- d. One 0.5 MG tank for Lahaina service area.

Stage VI: This stage starts operating in or about 1980 and consists of the following elements to provide for Lahaina and Ka-
anapali service areas.

- a. Honokowai Basal Well No. 1 at Elevation 670 with 2.25 MGD pump.
- b. 6,000 feet of 8-inch diameter cast iron connecting pipeline from the Honokowai source for Lahaina service area.

Stage VII: This stage starts operating in or about 1982 and consists of the following elements to provide for Honokowai, Kahana
and Kapalua service areas.

- a. Honolua Well No. 1 at Elevation 1250 with 1.80 MGD pump.
- b. 11,500 feet of 12-inch diameter cast iron connecting pipeline.

Stage VIII: This stage starts operating in or about 1987 and consists of the following elements to provide for Lahaina service area.

- a. Kanaha Basal Well at Elevation 700 with 2.00 MGD pump.

Stage IX: This stage starts operating in or about 1988 and consists of the following elements to provide for Kaanapali service area.

- a. Honokowai Basal Well No. 2 at Elevation 700 with 2.25 MGD pump.
- b. 3,000 feet of 10-inch diameter cast iron connecting pipeline.

Stage X: This stage starts operating in or about 1989 and consists of the following elements to provide for Honokowai, Kahana and Kapalua service areas.

- a. Honolulu Well No. 2 at Elevation 1400 with 1.75 MGD pump.
- b. 2,000 feet of 8-inch diameter cast iron connecting pipeline.

Basal Water

Stage I: This stage starts operating in or about 1971 and consists of the following elements to provide for Lahaina service area.

- a. Kanaha Well No. 1 at Elevation 700 with 1.50 MGD pump.
- b. 6,000 feet of 12-inch diameter cast iron connecting pipeline.
- c. One 0.5 MG tank.

Stage II: This stage starts operating in or about 1972 and consists of the following elements to provide for Kaanapali service area.

- a. Honokowai Well No. 1 at Elevation 700 with 2.25 MGD pump.
- b. 2,000 feet of 8-inch and 4,000 feet of 16-inch diameter cast iron connecting pipeline.

Stage III: This stage starts operating in or about 1973 and consists of the following elements to provide for Honokowai, Kahana and Kapalua service areas.

a. Honokahua Wells No. 1 and 2 and Elevations 900 and 1,000 with 1.80 MGD pumps.

b. 2,000 feet of 10-inch, 1,500 feet of 12-inch and 9,000 feet of 16-inch diameter cast iron connecting pipeline.

c. One 2.0 MG tank.

Stage IV: This stage starts operating in or about 1974 and consists of the following elements to provide for Kaanapali service area.

a. Honokowai Well No. 2 at Elevation 700 with 2.25 MGD pump.

b. 2,000 feet of 8-inch and 2,500 feet of 14-inch diameter cast iron connecting pipeline.

Stage V: This stage starts operating in or about 1976 and consists of the following elements to provide for Lahaina service area.

a. Kanaha Well No. 2 at Elevation 950 with 1.50 MGD pump.

b. 4,000 feet of 8-inch diameter cast iron connecting pipeline.

c. One 0.5 MG tank.

Stage VI: This stage starts operating in or about 1980 and consists of the following elements to provide for Lahaina and Kaanapali service areas.

a. Honokowai Well No. 3 at Elevation 700 with 2.25 MGD pump.

b. 3,000 feet of 12-inch diameter cast iron connecting pipeline.

c. 6,000 feet of 8-inch diameter cast iron connecting pipeline from the Honokowai source for Lahaina service area.

Stage VII: This stage starts operating in or about 1982 and consists of the following elements to provide for Honokowai, Kahana and Kapalua service areas.

a. Honolua Well No. 1 at Elevation 900 with 1.80 MGD pump.

b. 2,500 feet of 10-inch and 6,000 feet of 12-inch diameter cast iron connecting pipeline.

Stage VIII: This stage starts operating in or about 1987 and consists of the following elements to provide for Lahaina service area.

a. Kanaha Well No. 3 at Elevation 720 with 2.00 MGD pump.

b. 2,000 feet of 12-inch diameter cast iron connecting pipeline.

Stage IX: This stage starts operating in or about 1988 and consists of the following elements to provide for Kaanapali service area.

a. Honokowai Well No. 4 at Elevation 730 with 2.25 MGD pump.

b. 2,500 feet of 12-inch diameter cast iron connecting pipeline.








Stage X: This stage starts operating in or about 1989 and consists of the following elements to provide for Honokowai, Kahana and Kapalua service areas.

a. Honolua Well No. 2 at Elevation 1000 with 1.75 MGD pump.

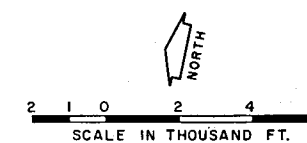
b. 1,000 feet of 8-inch diameter cast iron connecting pipeline.

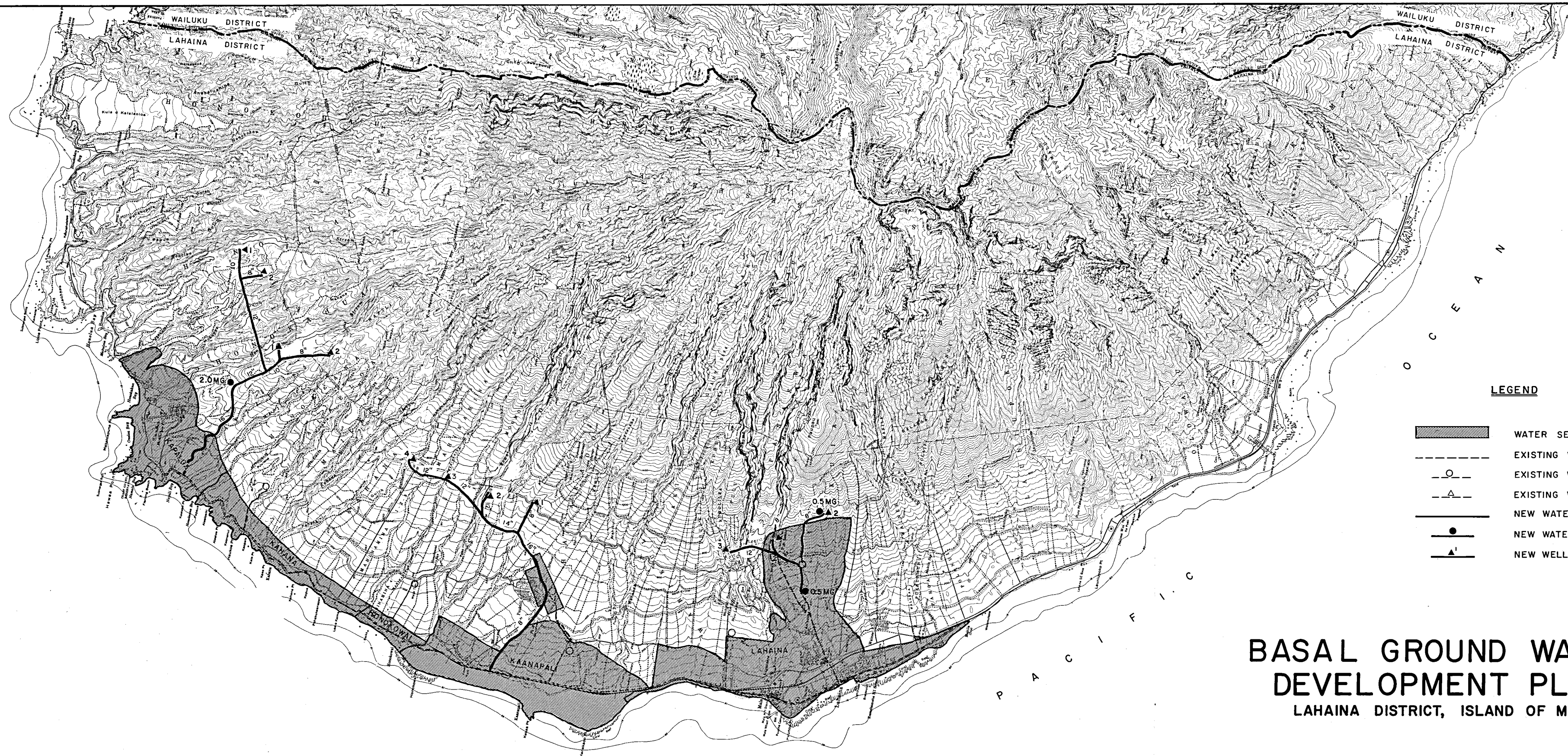


LEGEND


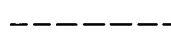





-  WATER SERVICE AREAS
-  EXISTING WATER LINES
-  EXISTING WATER TANK
-  EXISTING WELL
-  NEW WATER LINES
-  NEW WATER TANK
-  NEW WELL

HIGH LEVEL GROUND
WATER DEVELOPMENT PLAN
LAHAINA DISTRICT, ISLAND OF MAUI

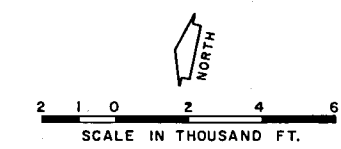


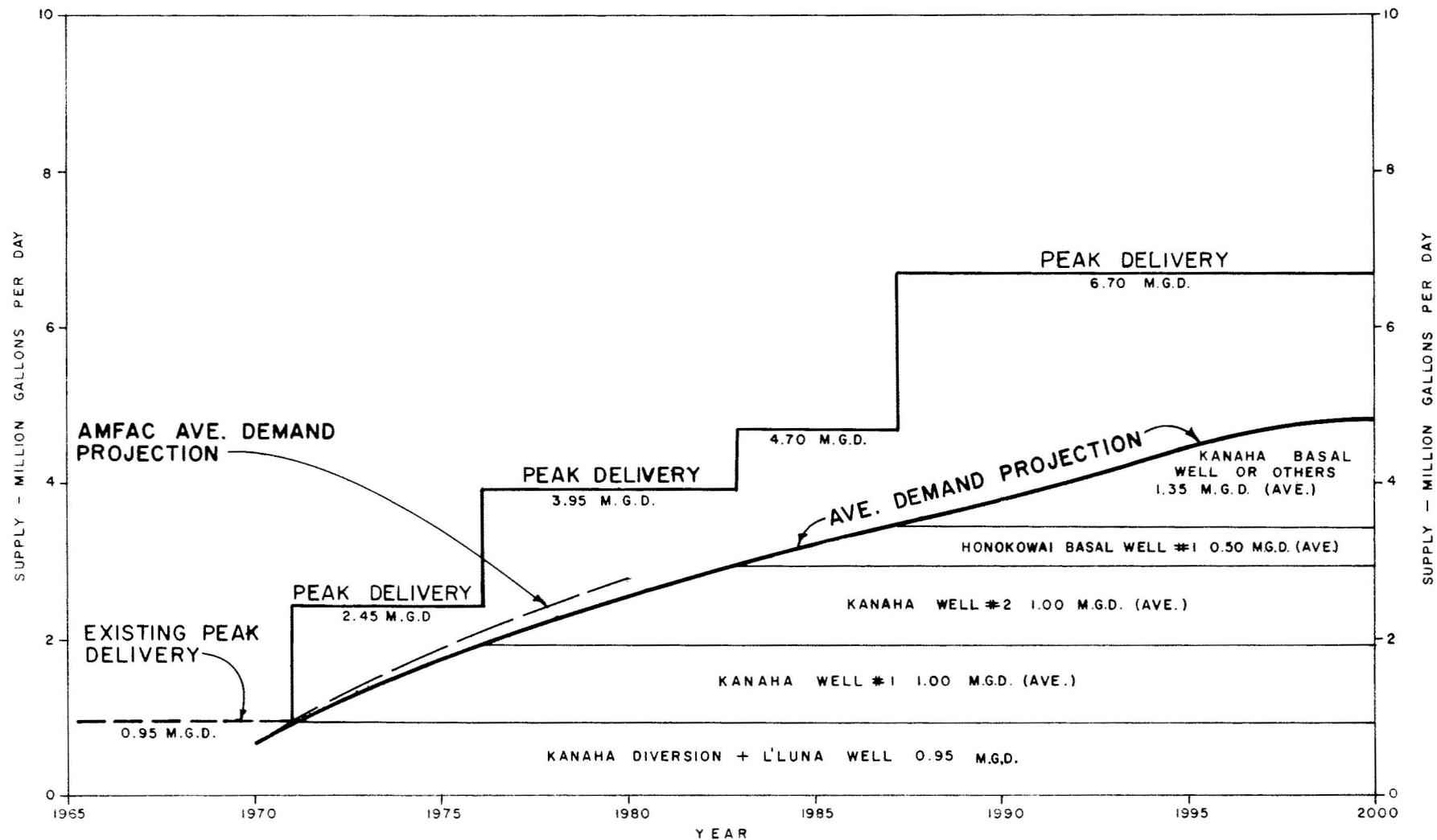


LEGEND

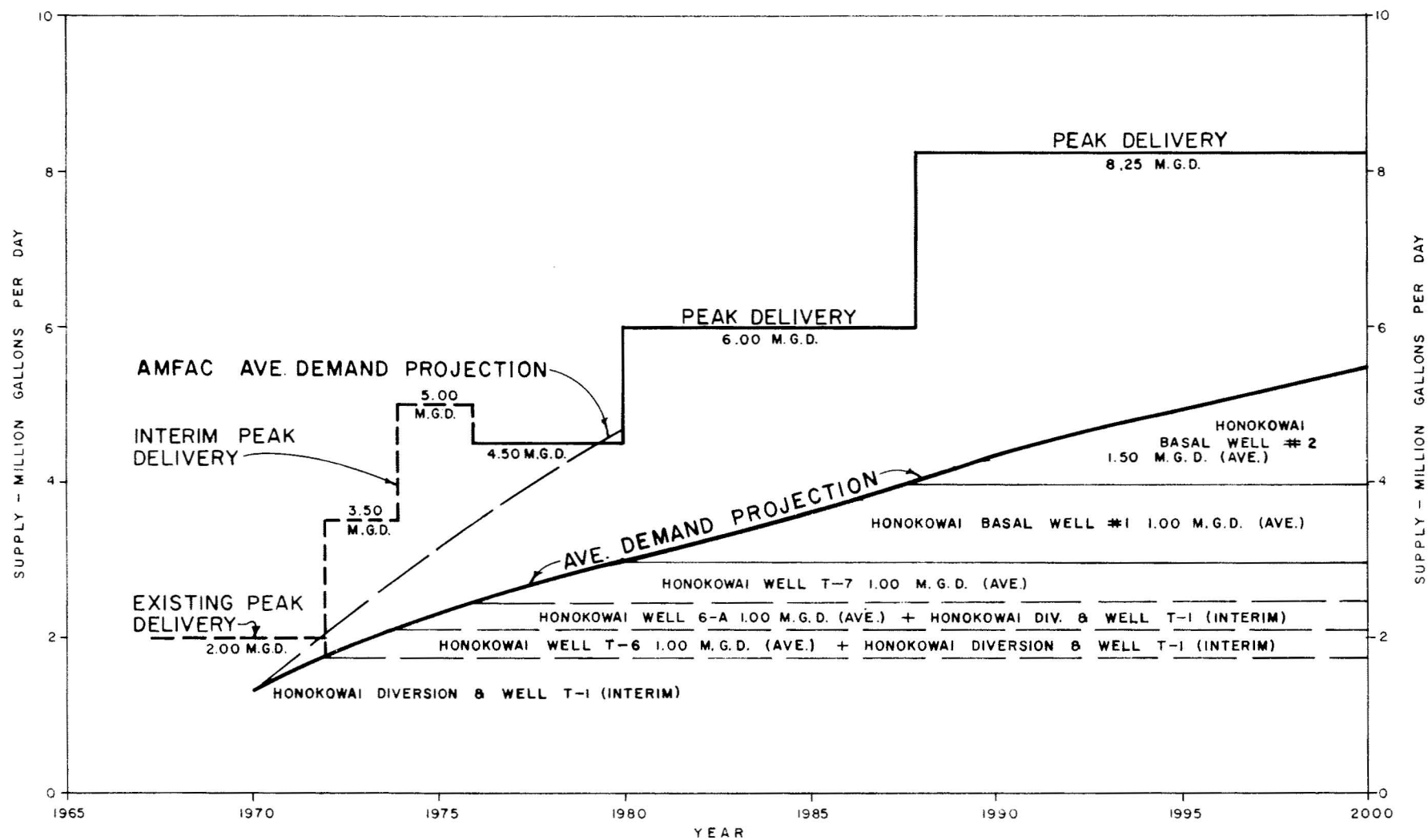
-  WATER SERVICE AREA
-  EXISTING WATER LINES
-  EXISTING WATER TANK
-  EXISTING WELL
-  NEW WATER LINES
-  NEW WATER TANK
-  NEW WELL

**BASAL GROUND WATER
DEVELOPMENT PLAN**
LAHAINA DISTRICT, ISLAND OF MAUI

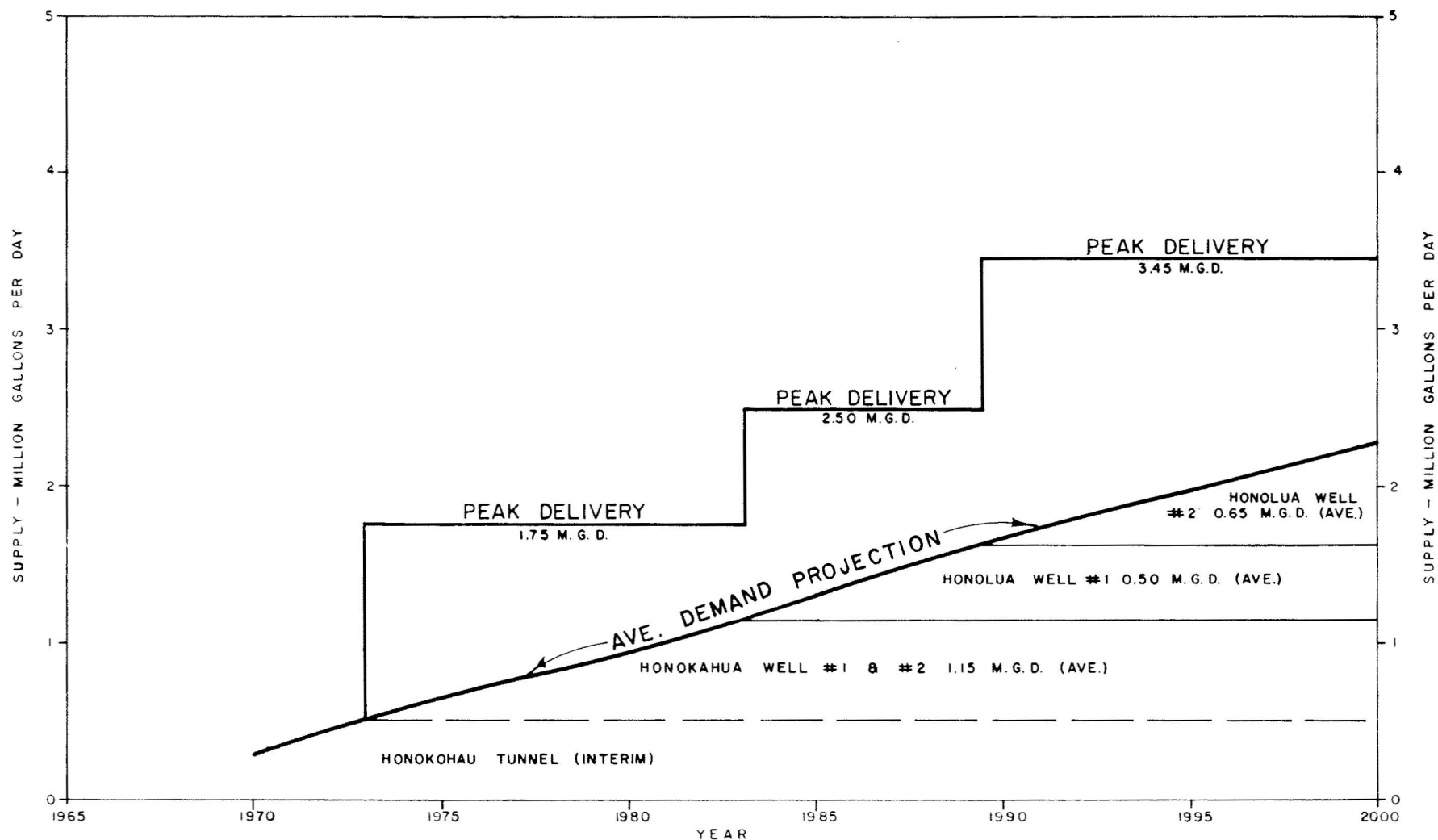




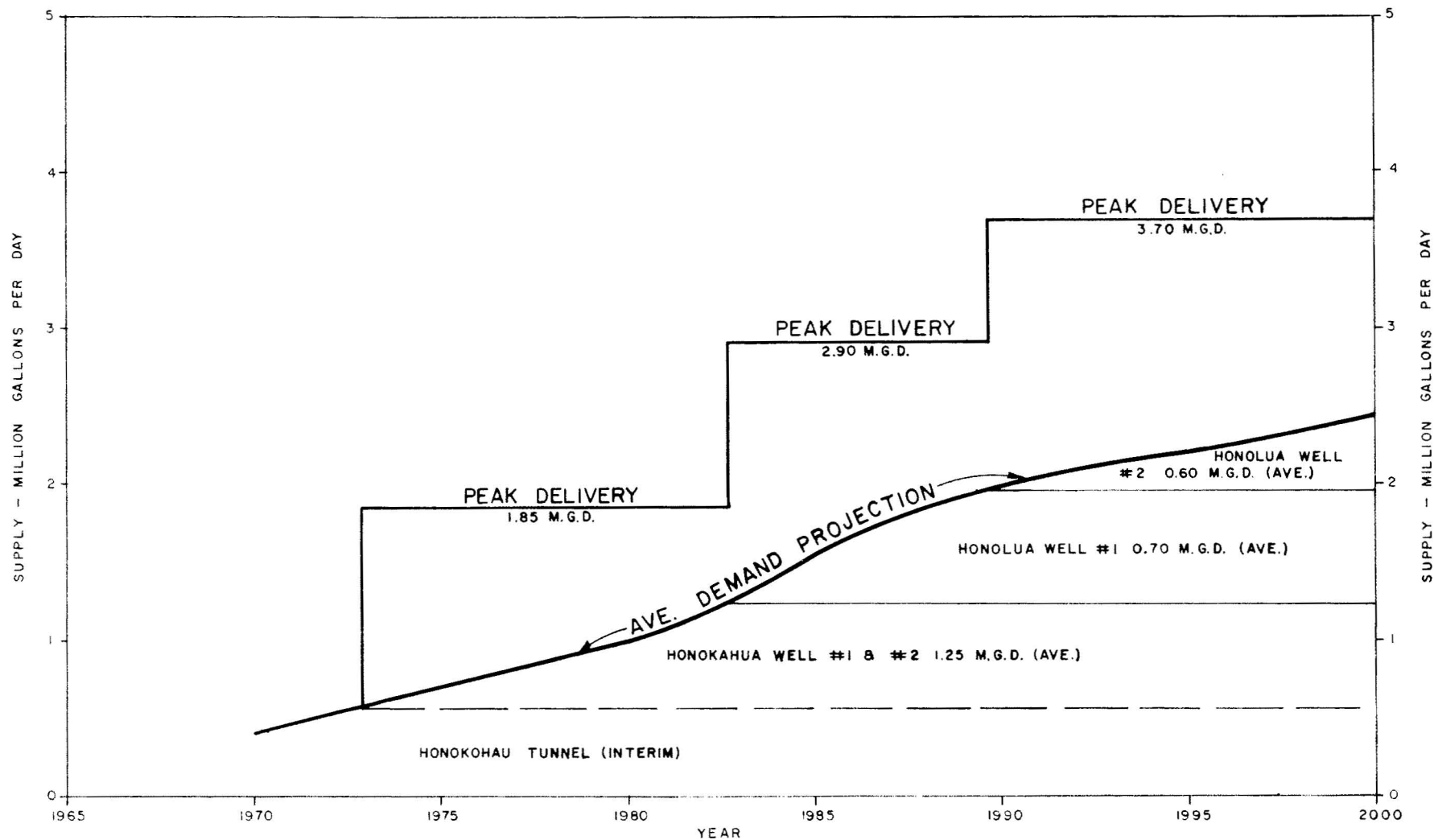
SUPPLY-DEMAND RELATIONSHIP FOR HIGH LEVEL GROUND WATER LAHAINA SERVICE AREA



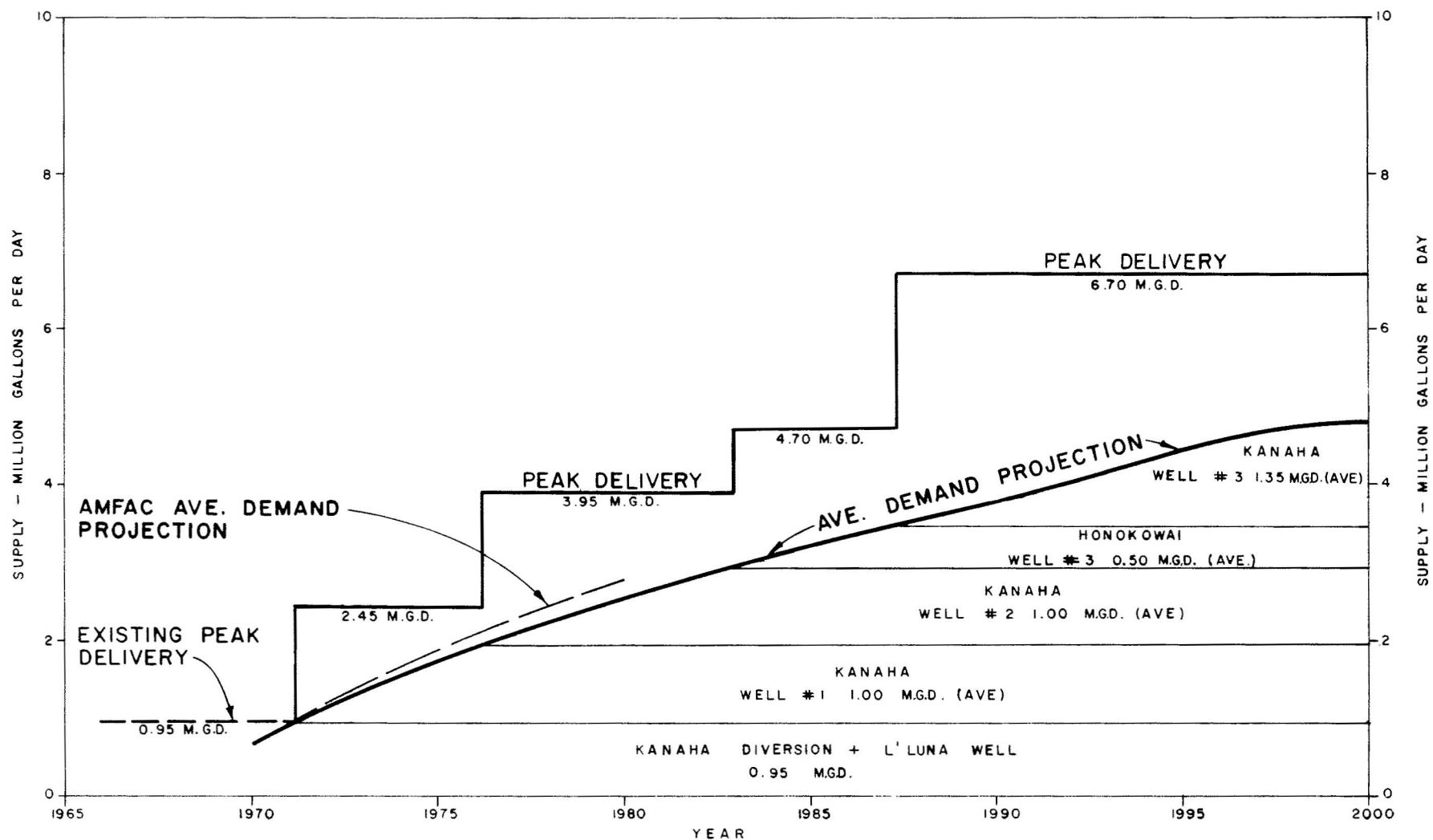
**SUPPLY-DEMAND RELATIONSHIP
FOR HIGH LEVEL GROUND WATER
KAANAPALI SERVICE AREA**



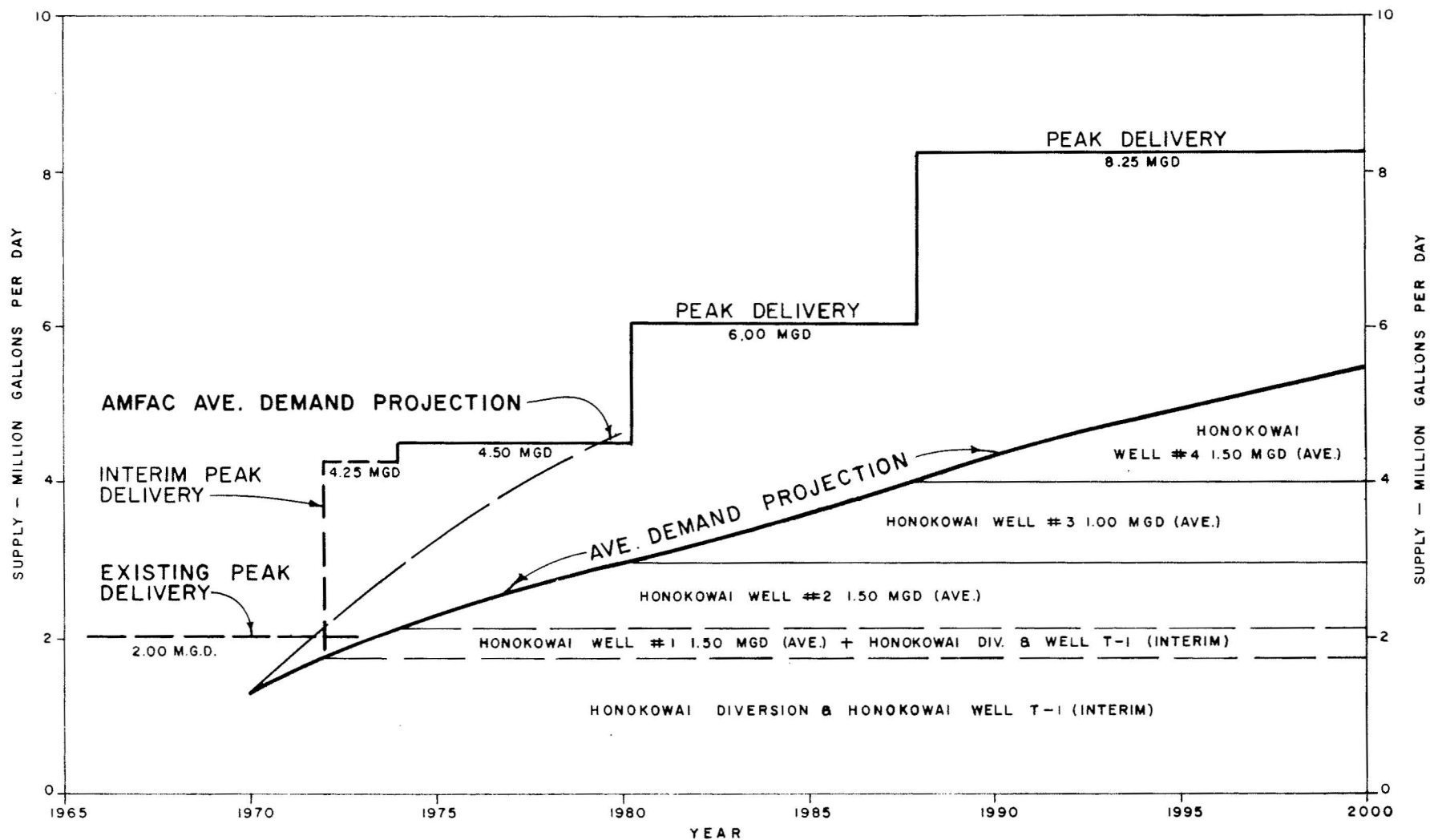
**SUPPLY-DEMAND RELATIONSHIP
FOR HIGH LEVEL GROUND WATER
HONOKOWAI - KAHANA SERVICE AREA**



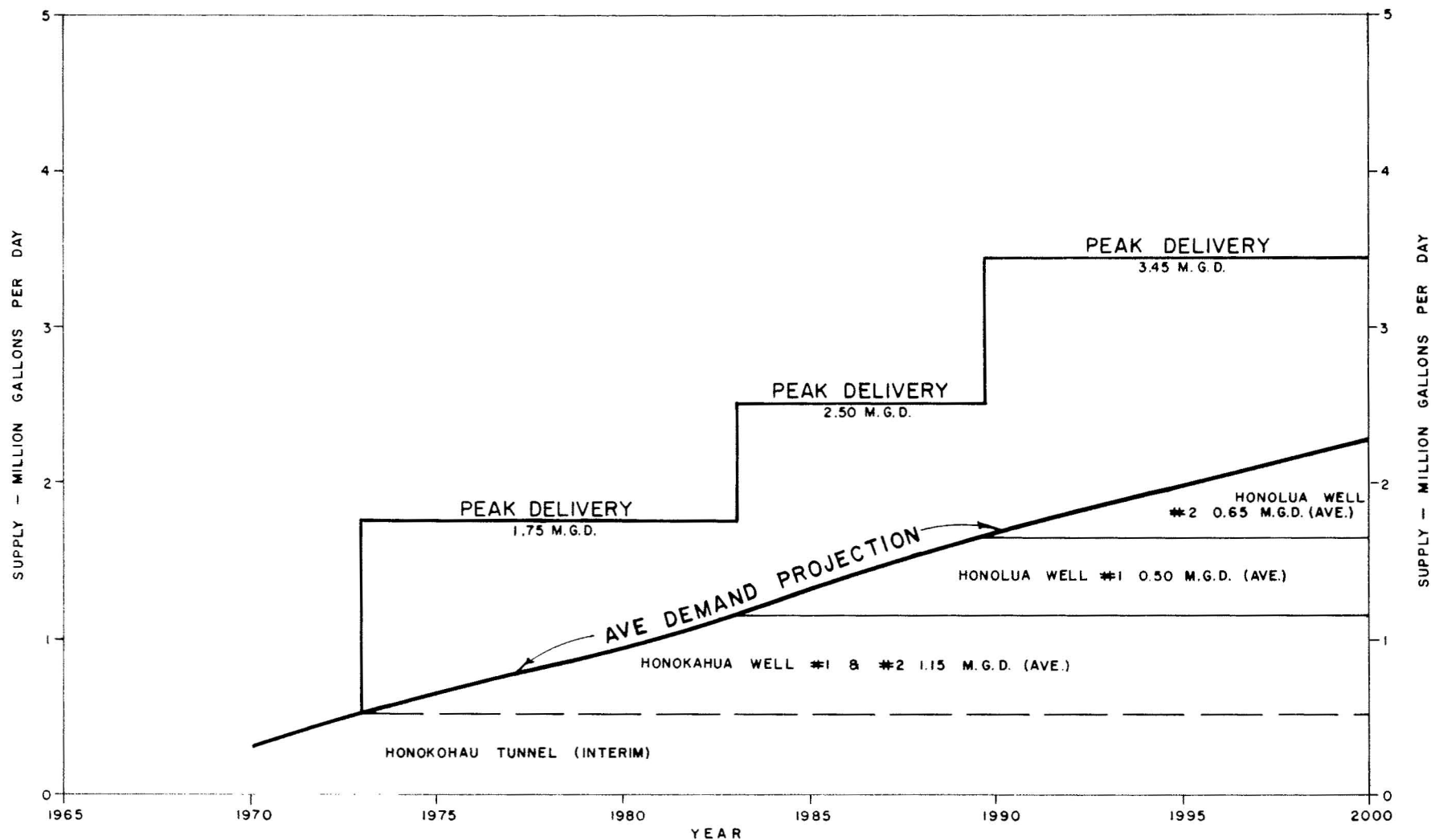
SUPPLY-DEMAND RELATIONSHIP FOR HIGH LEVEL GROUND WATER KAPALUA SERVICE AREA



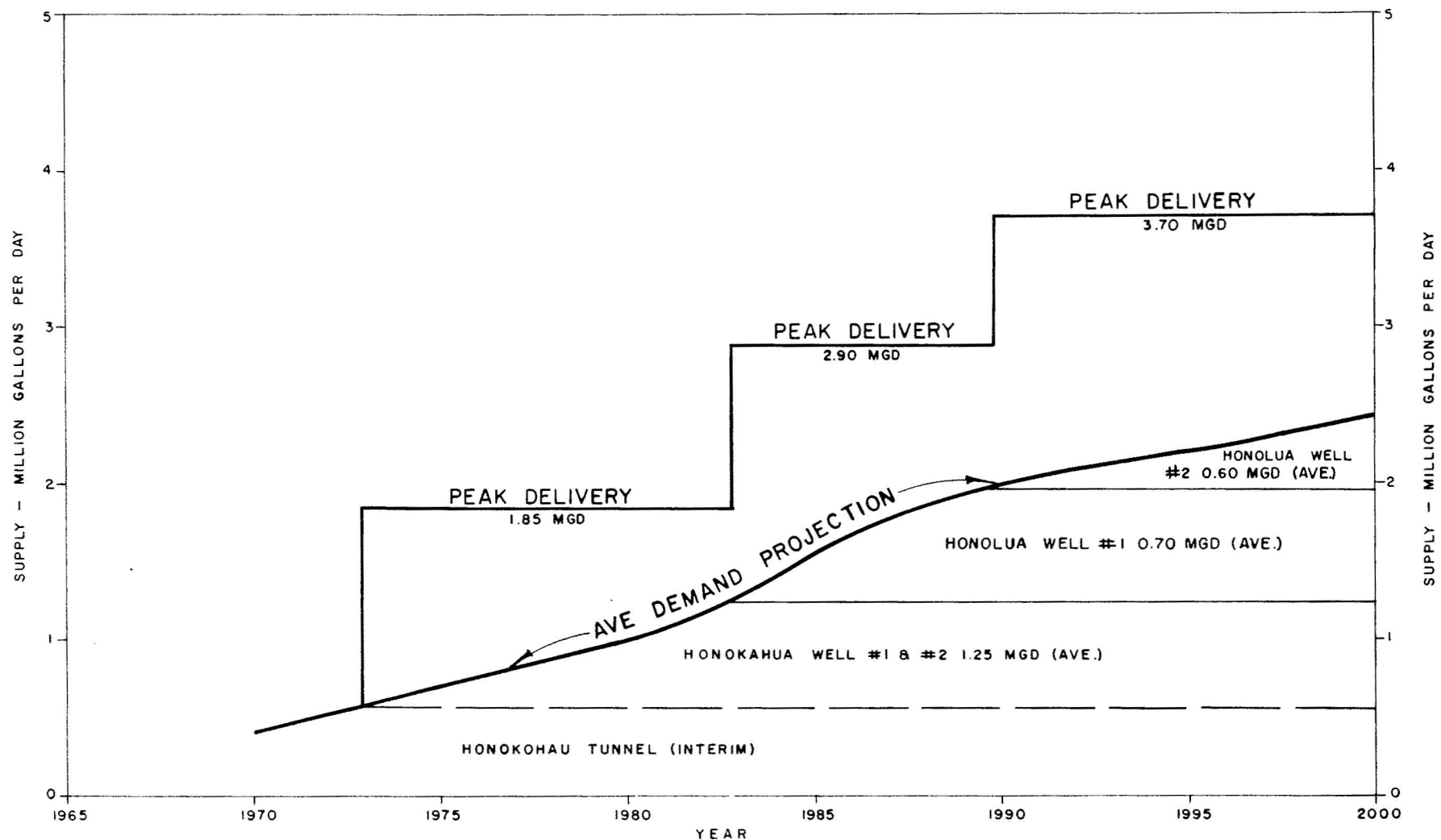
SUPPLY-DEMAND RELATIONSHIP FOR BASAL GROUND WATER LAHAINA SERVICE AREA



SUPPLY-DEMAND RELATIONSHIP FOR BASAL GROUND WATER KAANAPALI SERVICE AREA



SUPPLY-DEMAND RELATIONSHIP FOR BASAL GROUND WATER HONOKOWAI - KAHANA SERVICE AREA



SUPPLY-DEMAND RELATIONSHIP FOR BASAL GROUND WATER KAPALUA SERVICE AREA

TABLE 7

ESTIMATED COST FOR THE DEVELOPMENT
OF HIGH LEVEL GROUND WATER

Stage I

a.	One well with a 1.50 MGD pump	\$400,000	
b.	One 0.5 MG tank	140,000	
c.	10,000 feet of 12-inch diameter cast iron pipe	<u>240,000</u>	
	Total Estimated Cost for Stage I		\$ 780,000

Stage II

a.	One well with a 1.50 MGD pump	\$440,000	
b.	5,000 feet of 12-inch and 7,500 feet of 16-inch diameter cast iron pipes	<u>360,000</u>	
	Total Estimated Cost for Stage II		\$ 800,000

Stage III

a.	Two wells with two 1.80 MGD pumps	\$690,000	
b.	One 2.0 MG tank	350,000	
c.	1,500 feet of 8-inch, 5,000 feet of 10-inch, 6,000 feet of 12-inch and 9,000 feet of 16-inch diameter cast iron pipes	<u>560,000</u>	
	Total Estimated Cost for Stage III		\$1,600,000

Stage IV

a.	One well with a 1.50 MGD pump	\$185,000	
b.	2,000 feet of 10-inch diameter cast iron pipe	<u>40,000</u>	
	Total Estimated Cost for Stage IV		\$ 225,000

Stage V

a.	Two wells with two 1.50 MGD pumps	\$410,000	
b.	One 0.5 MG tank	140,000	
c.	7,000 feet of 8-inch diameter cast iron pipe	<u>110,000</u>	
	Total Estimated Cost for Stage V		\$ 660,000

Stage VI

a.	One well with a 2.25 MGD pump	\$175,000	
b.	6,000 feet of 8-inch diameter cast iron pipe	<u>95,000</u>	
	Total Estimated Cost for Stage VI		\$ 270,000

Stage VII

a.	One well with a 1.80 MGD pump	\$355,000	
b.	11,500 feet of 12-inch diameter cast iron pipe	<u>275,000</u>	
	Total Estimated Cost for Stage VII		\$ 630,000

Stage VIII

- a. One well with a 2.00
MGD pump \$180,000

Total Estimated Cost
for Stage VIII \$ 180,000

Stage IX

- a. One well with a 2.25
MGD pump \$220,000

- b. 3,000 feet of 10-inch
diameter cast iron pipe 60,000

Total Estimated Cost
for Stage IX \$ 280,000

Stage X

- a. One well with a 1.75
MGD pump \$185,000

- b. 2,000 feet of 8-inch
diameter cast iron pipe 35,000

Total Estimated Cost
for Stage X \$ 220,000

Total Estimated Cost
For Ten Stages \$5,645,000

TABLE 8

ESTIMATED COST FOR THE DEVELOPMENT
OF BASAL WATER

Stage I

a.	One well with a 1.50 MGD pump	\$265,000	
b.	One 0.5 MG tank	140,000	
c.	6,000 feet of 12-inch, diameter cast iron pipe	<u>145,000</u>	
	Total Estimated Cost for Stage I		\$ 550,000

Stage II

a.	One well with a 2.25 MGD pump	\$335,000	
b.	2,000 feet of 8-inch and 4,000 feet of 16- inch diameter cast iron pipes	<u>160,000</u>	
	Total Estimated Cost for Stage II		\$ 495,000

Stage III

a.	Two wells with two 1.80 MGD pumps	\$725,000	
b.	One 2.0 MG tank	350,000	
c.	2,000 feet of 10-inch, 1,500 feet of 12-inch and 9,000 feet of 16- inch diameter cast iron pipes	<u>365,000</u>	
	Total Estimated Cost for Stage III		\$1,440,000

Stage IV

a.	One well with a 2.25 MGD pump	\$230,000	
b.	2,000 feet of 8-inch and 2,500 feet of 14- inch diameter cast iron pipes	<u>100,000</u>	
	Total Estimated Cost for Stage IV		\$ 330,000

Stage V

a.	One well with a 1.50 MGD pump	\$280,000	
b.	One 0.5 MG tank	140,000	
c.	4,000 feet of 8-inch diameter cast iron pipe	<u>65,000</u>	
	Total Estimated Cost for Stage V		\$ 485,000

Stage VI

a.	One well with a 2.25 MGD pump	\$215,000	
b.	6,000 feet of 8-inch and 3,000 feet of 12- inch diameter cast iron pipes	<u>165,000</u>	
	Total Estimated Cost for Stage VI		\$ 380,000

Stage VII

a.	One well with a 1.80 MGD pump	\$380,000	
b.	2,500 feet of 10-inch and 6,000 feet of 12- inch diameter pipes	<u>190,000</u>	
	Total Estimated Cost for Stage VII		\$ 570,000

Stage VIII

a.	One well with a 2.00 MGD pump	\$205,000	
b.	2,000 feet of 12-inch diameter pipe	<u>50,000</u>	
	Total Estimated Cost for Stage VIII		\$ 255,000

Stage IX

a.	One well with a 2.25 MGD pump	\$210,000	
b.	2,500 feet of 12-inch diameter cast iron pipe	<u>60,000</u>	
	Total Estimated Cost for Stage IX		\$ 270,000

Stage X

a.	One well with a 1.75 MGD pump	\$240,000	
b.	1,000 feet of 8-inch diameter pipe	<u>15,000</u>	
	Total Estimated Cost for Stage X		\$ 255,000

Total Estimated Cost For Ten Stages	\$5,030,000
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APPENDIX

U.S.G.S. Area Designations A, B, & C

Honokohau Stream Flow Versus Diversion 1967

Honokohau Stream Flow Versus Diversion 1968

Estimated Stream Flow Available for Critical
Year, 1945 (Honokohau Stream)

Desalinization

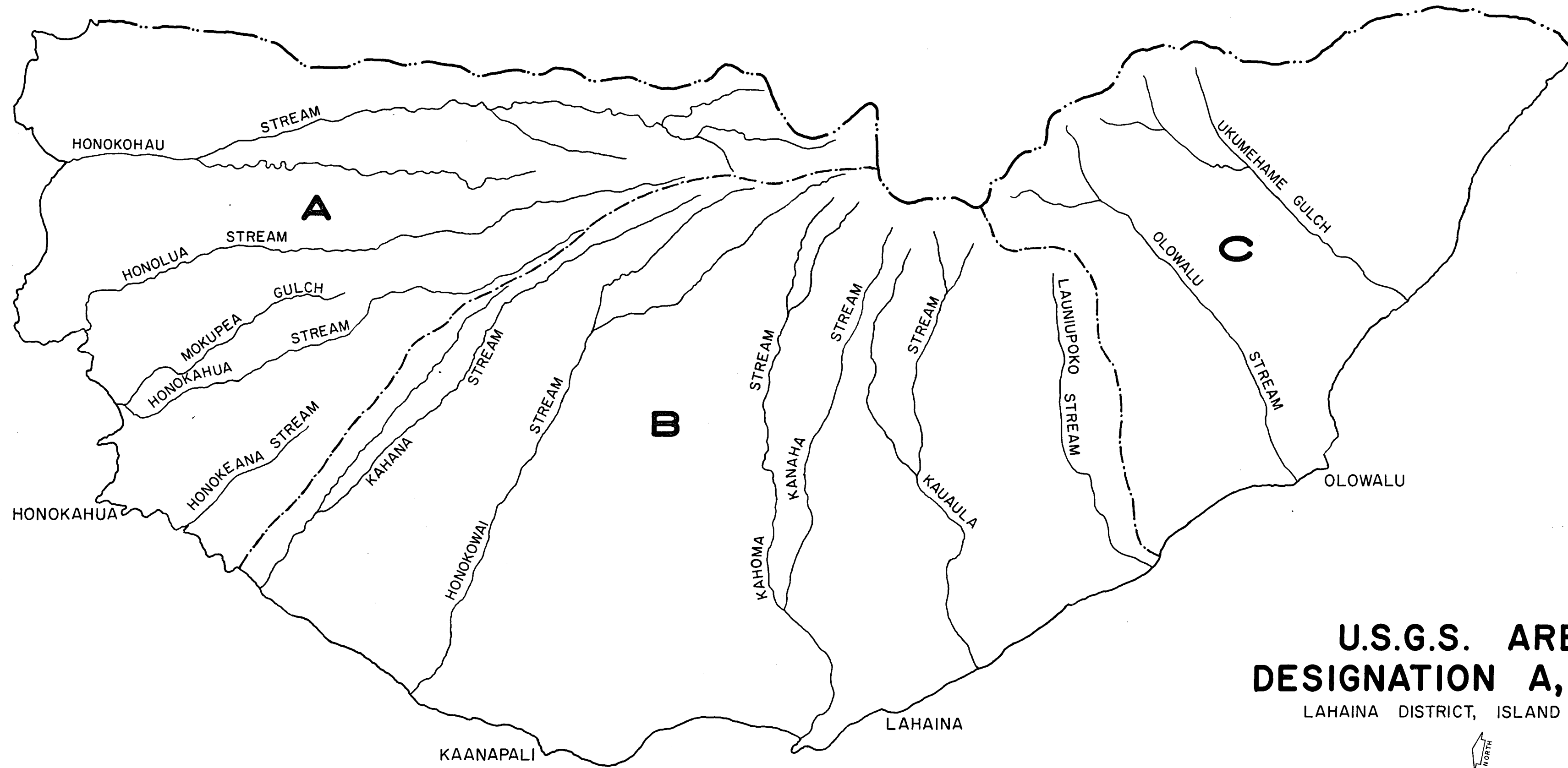
Evapo-transpiration Estimate

Unit Rainfall -- Runoff Plot

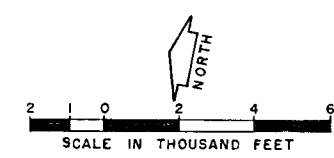
APPENDIX

U.S.G.S. Area Designations A, B, & C

Appendix 1



**U.S.G.S. AREA
DESIGNATION A, B, & C**
LAHAINA DISTRICT, ISLAND OF MAUI



APPENDIX

Honokohau Stream Flow Versus Diversion 1967

Appendix 2

	JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE			JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER		
DAYS	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.			
1	17.0	23.0	- 6.0	8.2	15.0	- 6.8	28.0	36.0	- 8.0	111.0	63.0	+ 48.0	24.0	31.0	- 7.0	13.0	21.0	- 8.0	10.0	18.0	- 8.0	11.0	18.0	- 7.0	11.0	18.0	- 7.0	10.0	17.0	- 7.0	109.0	41.0	+ 68.0	130.0	49.0	+ 81.0
2	24.0	28.0	- 4.0	8.2	15.0	- 6.8	16.0	24.0	- 8.0	26.0	35.0	- 9.0	15.0	26.0	- 11.0	11.0	20.0	- 9.0	9.7	17.0	- 7.3	12.0	19.0	- 7.0	11.0	18.0	- 7.0	10.0	18.0	- 8.0	110.0	65.0	+ 45.0	30.0	33.0	- 3.0
3	47.0	49.0	- 2.0	8.2	14.0	- 5.8	12.0	20.0	- 8.0	46.0	40.0	+ 6.0	15.0	21.0	- 6.0	11.0	18.0	- 7.0	9.7	17.0	- 7.3	110.0	59.0	+ 51.0	11.0	18.0	- 7.0	9.7	17.0	- 7.3	65.0	44.0	+ 21.0	65.0	44.0	+ 21.0
4	125.0	65.0	+ 60.0	8.0	14.0	- 6.0	12.0	20.0	- 8.0	15.0	24.0	- 9.0	13.0	20.0	- 7.0	11.0	18.0	- 7.0	16.0	24.0	- 8.0	19.0	26.0	- 7.0	10.0	17.0	- 7.0	9.0	16.0	- 7.0	18.0	23.0	- 5.0	54.0	34.0	+ 20.0
5	46.0	45.0	+ 1.0	8.7	16.0	- 6.3	12.0	20.0	- 8.0	78.0	51.0	+ 27.0	12.0	20.0	- 8.0	11.0	17.0	- 6.0	12.0	20.0	- 8.0	12.0	19.0	- 7.0	11.0	18.0	- 7.0	9.0	16.0	- 7.0	11.0	15.0	- 4.0	38.0	40.0	- 2.0
6	14.0	20.0	- 6.0	8.7	16.0	- 6.3	10.0	18.0	- 8.0	44.0	39.0	+ 5.0	19.0	26.0	- 7.0	10.0	17.0	- 7.0	10.0	18.0	- 8.0	11.0	18.0	- 7.0	12.0	19.0	- 7.0	9.0	16.0	- 7.0	9.7	14.0	- 4.3	14.0	21.0	- 7.0
7	11.0	18.0	- 7.0	8.0	15.0	- 7.0	15.0	23.0	- 8.0	71.0	60.0	+ 11.0	14.0	22.0	- 8.0	10.0	17.0	- 7.0	149.0	60.0	+ 89.0	19.0	26.0	- 7.0	14.0	21.0	- 7.0	9.0	16.0	- 7.0	9.7	14.0	- 4.3	20.0	27.0	- 7.0
8	14.0	20.0	- 6.0	7.7	15.0	- 8.3	10.0	17.0	- 7.0	47.0	49.0	- 2.0	12.0	20.0	- 8.0	10.0	17.0	- 7.0	23.0	31.0	- 8.0	70.0	48.0	+ 22.0	19.0	26.0	- 7.0	8.4	16.0	- 7.6	12.0	19.0	- 7.0	11.0	18.0	- 7.0
9	15.0	22.0	- 7.0	52.0	46.0	+ 6.0	13.0	23.0	- 10.0	19.0	26.0	- 7.0	17.0	25.0	- 8.0	10.0	17.0	- 7.0	12.0	29.0	- 8.0	23.0	29.0	- 6.0	11.0	18.0	- 7.0	8.4	16.0	- 7.6	22.0	38.0	- 16.0	14.0	22.0	- 8.0
10	9.5	16.0	- 6.5	111.0	48.0	+ 63.0	18.0	24.0	- 8.0	28.0	35.0	- 7.0	13.0	22.0	- 9.0	11.0	18.0	- 7.0	26.0	32.0	- 6.0	12.0	20.0	- 8.0	11.0	18.0	- 7.0	8.4	16.0	- 7.6	13.0	20.0	- 7.0	80.0	53.0	+ 27.0
11	57.0	47.0	+ 10.0	22.0	12.0	+ 10.0	9.8	17.0	- 7.2	52.0	48.0	+ 4.0	17.0	25.0	- 8.0	10.0	17.0	- 7.0	14.0	22.0	- 8.0	17.0	24.0	- 7.0	10.0	18.0	- 8.0	9.7	17.0	- 7.3	30.0	37.0	- 7.0	22.0	29.0	- 7.0
12	49.0	35.0	+ 14.0	14.0	9.2	+ 4.8	9.2	17.0	- 7.8	16.0	25.0	- 9.0	15.0	24.0	- 9.0	10.0	17.0	- 7.0	12.0	19.0	- 7.0	25.0	29.0	- 4.0	10.0	18.0	- 8.0	23.0	25.0	- 2.0	19.0	27.0	- 8.0	16.0	22.0	- 6.0
13	11.0	17.0	- 6.0	12.0	14.0	- 2.0	9.0	17.0	- 8.0	16.0	25.0	- 9.0	14.0	22.0	- 8.0	9.8	17.0	- 7.2	26.0	32.0	- 6.0	20.0	27.0	- 7.0	12.0	19.0	- 7.0	12.0	18.0	- 6.0	12.0	20.0	- 8.0	27.0	36.0	- 9.0
14	9.8	16.0	- 6.2	10.0	17.0	- 7.0	10.0	16.0	- 6.0	16.0	25.0	- 9.0	15.0	22.0	- 7.0	9.8	17.0	- 7.2	16.0	23.0	- 7.0	27.0	33.0	- 6.0	19.0	27.0	- 8.0	9.0	16.0	- 7.0	9.0	17.0	- 8.0	30.0	37.0	- 7.0
15	9.2	16.0	- 6.8	27.0	30.0	- 3.0	8.7	16.0	- 7.3	15.0	23.0	- 8.0	12.0	20.0	- 8.0	9.8	17.0	- 7.2	16.0	23.0	- 7.0	16.0	22.0	- 6.0	15.0	22.0	- 7.0	8.4	15.0	- 6.6	8.4	17.0	- 8.6	13.0	21.0	- 8.0
16	8.7	15.0	- 6.3	15.0	23.0	- 7.0	8.4	15.0	- 6.6	13.0	22.0	- 9.0	11.0	19.0	- 8.0	9.8	17.0	- 7.2	66.0	46.0	+ 20.0	53.0	42.0	+ 11.0	11.0	18.0	- 7.0	8.4	15.0	- 6.6	9.0	17.0	- 8.0	11.0	19.0	- 8.0
17	9.0	16.0	- 7.0	19.0	22.0	- 3.0	72.0	28.0	+ 44.0	13.0	21.0	- 8.0	12.0	20.0	- 8.0	9.8	17.0	- 7.2	54.0	50.0	+ 4.0	113.0	50.0	+ 63.0	10.0	17.0	- 7.0	8.4	15.0	- 6.6	9.0	17.0	- 8.0	10.0	18.0	- 8.0
18	12.0	19.0	- 7.0	27.0	30.0	- 3.0	13.0	13.0	0.0	13.0	21.0	- 8.0	47.0	48.0	- 1.0	9.8	17.0	- 7.2	36.0	36.0	0.0	42.0	36.0	+ 6.0	15.0	22.0	- 7.0	10.0	18.0	- 8.0	17.0	23.0	- 6.0	15.0	21.0	- 6.0
19	16.0	24.0	- 8.0	10.0	17.0	- 7.0	9.5	12.0	- 2.5	12.0	20.0	- 8.0	44.0	37.0	+ 7.0	9.5	17.0	- 7.5	19.0	27.0	- 8.0	14.0	21.0	- 7.0	10.0	18.0	- 8.0	9.7	17.0	- 7.3	14.0	22.0	- 8.0	16.0	24.0	- 8.0
20	11.0	17.0	- 6.0	12.0	19.0	- 7.0	9.0	14.0	- 5.0	12.0	20.0	- 8.0	48.0	37.0	+ 11.0	9.5	17.0	- 7.5	72.0	44.0	+ 28.0	39.0	40.0	- 1.0	12.0	18.0	- 6.0	18.0	26.0	- 8.0	32.0	34.0	- 2.0	43.0	31.0	+ 12.0
21	9.0	15.0	- 6.0	8.7	16.0	- 7.3	20.0	19.0	+ 1.0	12.0	20.0	- 8.0	13.0	21.0	- 8.0	9.5	17.0	- 7.5	85.0	44.0	+ 41.0	22.0	30.0	- 8.0	13.0	20.0	- 7.0	14.0	22.0	- 8.0	13.0	21.0	- 8.0	12.0	19.0	- 7.0
22	9.0	15.0	- 6.0	8.7	15.0	- 6.3	139.0	64.0	+ 75.0	12.0	20.0	- 8.0	12.0	20.0	- 8.0	9.5	17.0	- 7.5	46.0	46.0	0.0	14.0	21.0	- 7.0	12.0	18.0	- 6.0	17.0	25.0	- 8.0	21.0	29.0	- 8.0	10.0	18.0	- 8.0
23	8.4	15.0	- 6.6	18.0	24.0	- 6.0	51.0	43.0	+ 8.0	12.0	20.0	- 8.0	11.0	19.0	- 8.0	9.5	17.0	- 7.5	16.0	22.0	- 6.0	13.0	20.0	- 7.0	10.0	17.0	- 7.0	10.0	18.0	- 8.0	14.0	22.0	- 8.0	9.7	18.0	- 8.3
24	8.4	15.0	- 6.6	8.7	16.0	- 7.3	118.0																													

LOW IN M.C.D.

+ = OVERFLOW

- = FLOW FROM DEVELOPMENT TUNNELS

A = AVERAGE DEVELOPMENT TUNNEL FLOW TIMES NO. OF DAYS OVERFLOW

B = ADDITIONAL WATER AVAILABLE FOR DEVELOPMENT

C = AVERAGE DAILY WATER AVAILABLE FOR DEVELOPMENT

SOURCE: 1. MAUI PINEAPPLE COMPANY, LTD.
2. "SURFACE WATER RECORDS OF HAWAII AND OTHER PACIFIC AREAS".

APPENDIX

Honokohau Stream Flow Versus Diversion 1968

Appendix 3

HONOKOHAU									STREAM			VERSUS			DIVERSION																					
19									68																											
	JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE			JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER		
DAYS	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.	STREAM FLOW	DIVER.	DIFF.			
1	11.0	18.0	- 7.0	9.0	16.0	- 7.0	8.4	16.0	- 7.6				25.0	35.0	- 10.0	14.0	22.0	- 8.0	12.0	20.0	- 8.0	40.0	35.0	+ 5.0	14.0	22.0	- 8.0	7.1	15.0	- 7.9	7.1	14.0	- 6.9	9.0	17.0	- 8.0
2	12.0	21.0	- 9.0	9.0	16.0	- 7.0	8.4	16.0	- 7.6				21.0	31.0	- 10.0	13.0	22.0	- 9.0	11.0	19.0	- 8.0	12.0	19.0	- 7.0	8.4	17.0	- 8.6	65.0	41.0	+ 24.0	7.1	14.0	- 6.9	9.0	16.0	- 7.0
3	52.0	36.0	+ 16.0	8.4	16.0	- 7.6	76.0	55.0	+ 21.0				17.0	27.0	- 10.0	13.0	22.0	- 9.0	11.0	19.0	- 8.0	12.0	20.0	- 8.0	8.4	16.0	- 7.6	13.0	19.0	- 6.0	7.1	13.0	- 5.9	17.0	25.0	- 8.0
4	76.0	44.0	+ 32.0	8.4	16.0	- 7.6	103.0	59.0	+ 44.0				16.0	26.0	- 10.0	13.0	22.0	- 9.0	11.0	19.0	- 8.0	16.0	24.0	- 8.0	8.4	16.0	- 7.6	8.4	16.0	- 7.6	6.5	13.0	- 6.5	107.0	49.0	+ 58.0
5	28.0	34.0	- 6.0	8.4	16.0	- 7.6	59.0	45.0	+ 14.0				19.0	29.0	- 10.0	13.0	22.0	- 9.0	11.0	19.0	- 8.0	13.0	21.0	- 8.0	7.8	16.0	- 8.2	7.8	15.0	- 7.2	6.5	13.0	- 6.5	18.0	26.0	- 8.0
6	12.0	21.0	- 9.0	8.4	15.0	- 6.6	12.0	20.0	- 8.0				16.0	26.0	- 10.0	13.0	22.0	- 9.0	11.0	19.0	- 8.0	11.0	18.0	- 7.0	34.0	27.0	+ 7.0	7.1	15.0	- 7.9	6.5	13.0	- 6.5	12.0	19.0	- 7.0
7	10.0	18.0	- 8.0	12.0	19.0	- 7.0	10.0	18.0	- 8.0				16.0	25.0	- 9.0	14.0	22.0	- 8.0	11.0	19.0	- 8.0	10.0	18.0	- 8.0	16.0	26.0	- 10.0	7.8	15.0	- 7.2	6.5	13.0	- 6.5	8.4	16.0	- 7.6
8	9.7	18.0	- 8.3	9.7	16.0	- 6.3	9.7	18.0	- 8.3				16.0	25.0	- 9.0	16.0	25.0	- 9.0	11.0	19.0	- 8.0	9.7	17.0	- 7.3	28.0	29.0	- 1.0	7.1	15.0	- 7.9	6.5	13.0	- 6.5	8.4	15.0	- 6.6
9	9.0	17.0	- 8.0	8.4	15.0	- 6.6	9.0	17.0	- 8.0				16.0	25.0	- 9.0	14.0	24.0	-10.0	11.0	19.0	- 8.0	9.7	17.0	- 7.3	11.0	19.0	- 8.0	7.1	14.0	- 6.9	6.5	13.0	- 6.5	8.4	15.0	- 6.6
10	9.0	17.0	- 8.0	8.4	15.0	- 6.6	34.0	37.0	- 3.0				30.0	34.0	- 4.0	16.0	25.0	- 9.0	11.0	19.0	- 8.0	14.0	21.0	- 7.0	9.7	17.0	- 7.3	7.1	14.0	- 6.9	8.4	15.0	- 6.4	8.4	15.0	- 6.6
11	9.0	17.0	- 8.0	8.4	15.0	- 6.6	77.0	50.0	+ 27.0				17.0	29.0	- 12.0	18.0	27.0	- 9.0	15.0	24.0	- 9.0	21.0	30.0	- 9.0	8.4	16.0	- 7.6	7.1	14.0	- 6.9	7.1	14.0	- 6.9	7.1	14.0	- 6.9
12	9.0	17.0	- 8.0	8.4	15.0	- 6.6	63.0	44.0	+ 19.0				16.0	25.0	- 9.0	14.0	24.0	-10.0	12.0	20.0	- 8.0	48.0	42.0	+ 6.0	8.4	16.0	- 7.6	7.1	14.0	- 6.9	6.5	13.0	- 6.5	78.0	26.0	+ 52.0
13	9.0	17.0	- 8.0	8.4	15.0	- 6.6	160.0	65.0	+ 95.0				16.0	25.0	- 9.0	43.0	32.0	-11.0	12.0	20.0	- 8.0	14.0	22.0	- 8.0	8.4	16.0	- 7.6	7.1	14.0	- 6.9	6.5	13.0	- 6.5	227.0	65.0	+162.0
14	9.0	17.0	- 8.0	8.4	15.0	- 6.6	81.0	55.0	+ 26.0				15.0	25.0	- 10.0	17.0	26.0	- 9.0	21.0	28.0	- 7.0	19.0	26.0	- 7.0	7.8	15.0	- 7.2	7.1	14.0	- 6.9	6.5	13.0	- 6.5	35.0	41.0	- 6.0
15	8.4	16.0	- 7.6	24.0	25.0	- 1.0	86.0	53.0	+ 33.0				14.0	24.0	- 10.0	14.0	22.0	- 8.0	13.0	20.0	- 7.0	10.0	17.0	- 7.0	8.4	16.0	- 7.6	12.0	20.0	- 8.0	6.5	13.0	- 6.5	13.0	21.0	- 8.0
16	15.0	24.0	- 9.0	34.0	34.0	0.0	267.0	52.0	+215.0				15.0	24.0	- 9.0	17.0	27.0	-10.0	11.0	19.0	- 8.0	9.0	17.0	- 8.0	8.4	16.0	- 7.6	8.4	15.0	- 6.6	8.4	15.0	- 6.6	20.0	25.0	- 5.0
17	33.0	32.0	+ 1.0	81.0	50.0	+ 31.0				56.0	36.0	+ 20.0	16.0	25.0	- 9.0	23.0	31.0	- 8.0	19.0	30.0	- 11.0	9.0	17.0	- 8.0	8.4	16.0	- 7.6	9.0	16.0	- 7.0	6.5	13.0	- 6.5	24.0	29.0	- 5.0
18	14.0	22.0	- 8.0	15.0	21.0	- 6.0				81.0	43.0	+ 38.0	14.0	24.0	- 10.0	19.0	28.0	- 9.0	12.0	19.0	- 7.0	19.0	26.0	- 7.0	7.8	15.0	- 7.2	7.1	14.0	- 6.9	6.5	13.0	- 6.5	19.0	26.0	- 7.0
19	19.0	25.0	- 6.0	9.7	17.0	- 7.3				144.0	42.0	+102.0	14.0	24.0	- 10.0	26.0	31.0	- 5.0	12.0			10.0	18.0	- 8.0	8.4	15.0	- 6.6	14.0	21.0	- 7.0	6.5	13.0	- 6.5	20.0	23.0	- 3.0
20	34.0	34.0	0.0	9.0	16.0	- 7.0				26.0	24.0	+ 2.0	14.0	24.0	- 10.0	14.0	23.0	- 9.0	12.0			14.0	22.0	- 8.0	9.7	18.0	- 8.3	23.0	27.0	- 4.0	6.5	13.0	- 6.5	22.0	54.0	- 32.0
21	11.0	18.0	- 7.0	107.0	38.0	+ 69.0				24.0	25.0	- 1.0	16.0	26.0	- 10.0	12.0	21.0	- 9.0	12.0			14.0	23.0	- 9.0	9.0	17.0	- 8.0	7.8	15.0	- 7.2	6.5	13.0	- 6.5	12.0	17.0	- 5.0
22	9.7	17.0	- 7.3	12.0	19.0	- 7.0				--	28.0	--	14.0	24.0	- 10.0	13.0	21.0	- 8.0	11.0			9.7	18.0	- 8.3	7.8	15.0	- 7.2	15.0	22.0	- 7.0	6.5	13.0	- 6.5	35.0	36.0	- 1.0
23	9.7	17.0	- 7.3	10.0	17.0	- 7.0				35.0	41.0	- 6.0	14.0	23.0	- 9.0	16.0	29.0	-13.0	55.0			9.0	17.0	- 8.0	10.0	18.0	- 8.0	9.7	17.0	- 7.3	7.8	14.0	- 6.2	12.0	19.0	- 7.0
24	9.7	16.0	- 6.3	9.0	16.0	- 7.0				45.0	42.0	+ 3.0	14.0	23.0	- 9.0	14.0	23.0	- 9.0	12.0			8.4	16.0	- 7.6	28.0	30.0	- 2.0	7.1	14.0	- 6.9	17.0	21.0	- 4.0	9.0	16.0	- 7.0
25	9.0	16.0	- 7.0	27.0	28.0	- 1.0				44.0	43.0	+ 1.0	19.0	27.0	- 8.0	19.0	25.0	- 6.0	23.0			9.0	17.0	- 8.0	21.0	28.0	- 7.0	7.1	14.0	- 6.9	9.7	16.0	- 6.3	59.0	40.0	+ 19.0
26	9.0	16.0	- 7.0	12.0	18.0	- 6.0			</																											

APPENDIX

Estimated Stream Flow Available For
Year, 1945 (Honokohau Stream)

ESTIMATED STREAM FLOW AVAILABLE FOR CRITICAL YEAR (1945)
HONOKOHAU STREAM

	JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE			JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER			
DAYS	STREAM FLOW	EST. ADD'L. AVAIL.		STREAM FLOW	EST. ADD'L. AVAIL.		STREAM FLOW	EST. ADD'L. AVAIL.		STREAM FLOW	EST. ADD'L. AVAIL.		STREAM FLOW	EST. ADD'L. AVAIL.		STREAM FLOW	EST. ADD'L. AVAIL.		STREAM FLOW	EST. ADD'L. AVAIL.		STREAM FLOW	EST. ADD'L. AVAIL.		STREAM FLOW	EST. ADD'L. AVAIL.		STREAM FLOW	EST. ADD'L. AVAIL.		STREAM FLOW	EST. ADD'L. AVAIL.		STREAM FLOW	EST. ADD'L. AVAIL.		
1	8.7	0.0		7.6	0.0		11.3	0.0		7.6	0.0		7.5	0.0		7.1	0.0		31.0	5.0		11.3	0.0		7.3	0.0		6.2	0.0		11.3	0.0		5.8	0.0		
2	8.7	0.0		7.6	0.0		27.0	0.0		7.6	0.0		12.4	0.0		12.0	0.0		48.0	6.0		13.7	0.0		8.0	0.0		6.6	0.0		18.9	0.0		24.5	0.0		
3	8.5	0.0		7.6	0.0		26.5	0.0		7.6	0.0		9.3	0.0		9.2	0.0		8.0	0.0		7.3	0.0		14.4	0.0		6.6	0.0		8.7	0.0		86.0	40.0		
4	8.5	0.0		7.6	0.0		47.0	6.0		7.6	0.0		8.0	0.0		7.6	0.0		7.6	0.0		6.9	0.0		9.8	0.0		6.2	0.0		7.6	0.0		52.0	10.0		
5	8.5	0.0		7.6	0.0		25.0	0.0		7.6	0.0		7.6	0.0		13.8	0.0		6.9	0.0		105.0	65.0		12.2	0.0		6.2	0.0		6.9	0.0		10.6	0.0		
6	8.2	0.0		7.8	0.0		27.5	0.0		19.2	0.0		7.6	0.0		8.7	0.0		6.9	0.0		66.0	30.0		9.5	0.0		6.2	0.0		8.4	0.0		7.3	0.0		
7	8.2	0.0		7.6	0.0		33.5	2.0		10.0	65.0		7.6	0.0		9.7	0.0		6.6	0.0		20.5	0.0		16.6	0.0		6.2	0.0		11.4	0.0		7.1	0.0		
8	8.2	0.0		7.6	0.0		77.0	30.0		96.0	65.0		7.6	0.0		14.3	0.0		6.4	0.0		15.4	0.0		7.3	0.0		6.1	0.0		9.8	0.0		6.9	0.0		
9	8.2	0.0		7.6	0.0		36.0	4.0		14.1	0.0		7.6	0.0		9.8	0.0		6.6	0.0		15.7	0.0		6.9	0.0		8.2	0.0		32.0	4.0		6.4	0.0		
10	8.2	0.0		7.3	0.0		13.7	0.0		9.3	0.0		7.3	0.0		7.6	0.0		13.7	0.0		13.2	0.0		8.9	0.0		7.0	0.0		25.0	0.0		6.6	0.0		
11	8.2	0.0		7.3	0.0		18.3	0.0		9.3	0.0		7.3	0.0		10.4	0.0		19.9	0.0		20.5	0.0		24.0	0.0		6.4	0.0		12.3	0.0		15.7	0.0		
12	8.2	0.0		7.3	0.0		17.0	0.0		8.7	0.0		7.3	0.0		10.0	0.0		7.3	0.0		11.0	0.0		7.1	0.0		6.2	0.0		7.3	0.0		28.0	0.0		
13	8.2	0.0		7.3	0.0		80.0	40.0		15.9	0.0		7.3	0.0		13.7	0.0		6.6	0.0		8.0	0.0		6.6	0.0		6.2	0.0		7.8	0.0		7.8	0.0		
14	8.2	0.0		8.2	0.0		11.5	0.0		38.5	4.0		7.1	0.0		16.7	0.0		6.7	0.0		8.0	0.0		20.5	0.0		6.4	0.0		7.1	0.0		6.6	0.0		
15	8.2	0.0		7.6	0.0		11.2	0.0		22.0	0.0		7.3	0.0		7.8	0.0		14.3	0.0		30.5	4.0		14.3	0.0		8.3	0.0		6.6	0.0		6.4	0.0		
16	8.0	0.0		7.8	0.0		73.0	30.0		43.0	6.0		7.6	0.0		7.6	0.0		45.0	6.0		15.9	0.0		11.3	0.0		11.0	0.0		6.4	0.0		6.2	0.0		
17	18.5	0.0		8.5	0.0		65.0	30.0		23.5	0.0		7.1	0.0		7.5	0.0		7.8	0.0		8.0	0.0		10.7	0.0		6.9	0.0		6.2	0.0		6.2	0.0		
18	9.6	0.0		7.8	0.0		27.0	0.0		11.6	0.0		8.5	0.0		8.7	0.0		6.9	0.0		39.0	4.0		8.2	0.0		22.0	0.0		6.2	0.0		6.0	0.0		
19	8.2	0.0		7.6	0.0		15.2	0.0		9.0	0.0		13.9	0.0		13.4	0.0		6.9	0.0		13.4	0.0		6.9	0.0		8.0	0.0		6.0	0.0		6.0	0.0		
20	8.0	0.0		7.6	0.0		15.3	0.0		8.7	0.0		9.8	0.0		32.5	4.0		7.6	0.0		20.0	0.0		6.4	0.0		7.8	0.0		6.0	0.0		6.2	0.0		
21	8.0	0.0		12.6	0.0		9.5	0.0		9.0	0.0		7.6	0.0		22.0	0.0		6.9	0.0		9.3	0.0		6.4	0.0		6.4	0.0		6.0	0.0		6.0	0.0		
22	22.0	0.0		17.1	0.0		8.7	0.0		8.2	0.0		7.1	0.0		14.5	0.0		7.3	0.0		7.8	0.0		6.4	0.0		6.0	0.0		6.0	0.0		6.0	0.0		
23	8.7	0.0		11.2	0.0		8.2	0.0		8.2	0.0		7.1	0.0		35.0	4.0		8.4	0.0		34.5	4.0		6.2	0.0		6.4	0.0		56.0	10.0		6.0	0.0		
24	8.2	0.0		10.8	0.0		14.6	0.0		11.1	0.0		7.1	0.0		9.5	0.0		7.3	0.0		82.0	40.0		6.0	0.0		6.6	0.0		16.2	0.0		5.8	0.0		
25	8.0	0.0		13.5	0.0		9.5	0.0		9.5	0.0		7.1	0.0		10.1	0.0		7.1	0.0		15.8	0.0		6.0	0.0		6.0	0.0		8.0	0.0		5.8	0.0		
26	8.0	0.0		16.7	0.0		8.2	0.0		8.2	0.0		7.1	0.0		15.1	0.0		6.9	0.0		8.7	0.0		6.0	0.0		12.8	0.0		6.4	0.0		5.8	0.0		
27	7.8	0.0		35.0	0.4		8.0	0.0		8.0	0.0		7.1	0.0		10.8	0.0		6.9	0.0		8.2	0.0		6.0	0.0		22.0	0.0		6.2	0.0		5.8	0.0		
28	7.8	0.0		10.9	0.0		18.4	0.0		7.6	0.0		7.3	0.0		8.2	0.0		9.2	0.0		7.8	0.0		6.0	0.0		14.5	0.0		6.0	0.0		5.8	0.0		
29	7.8	0.0					14.8	0.0		7.8	0.0		6.9	0.0		7.6	0.0		8.0	0.0		8.7	0.0		6.0	0.0		43.0	6.0		6.0	0.0		5.6	0.0		
30	7.6	0.0					9.4	0.0		8.0	0.0		6.9	0.0		7.6	0.0		43.0	6.0		9.3	0.0		6.0	0.0		50.0	10.0		5.8	0.0		5.6	0.0		
31	7.6	0.0					8.0	0.0					7.1	0.0					11.0	0.0		8.7	0.0					29.5	0.0					5.6			
	279.0	0.0		281.0	4.0		775.0	142.0		562.0	140.0		244.0	0.0		369.0	8.0		39.3	23.0		650.0	147.0		278.0	0.0		358.0	16.0		335.0	14.0		372.0	50.0		
A		0.0			5.0			35.0			20.0			0.0			10.0			20.0			30.0			0.0			10.0			10.0			10.0		
B		0.0			9.0			177.0			160.0			0.0			18.0			43.0			177.0			0.0			26.0			24.0			60.0		
C		0.0			0.3			5.9			5.4			0.0			0.6			1.4			5.7			0.0			0.8			0.8			1.9		

A = AVERAGE DEVELOPMENT TUNNEL FLOW TIMES NO. OF DAYS OVERFLOW
B = ADDITIONAL WATER AVAILABLE FOR DEVELOPMENT
C = AVERAGE DAILY WATER AVAILABLE FOR DEVELOPMENT

SOURCE: "SURFACE WATER SUPPLY OF HAWAII".

APPENDIX

Desalinization

There are two sources of water, potentially potable, that cannot be dismissed from any water resource study for coastal areas of the Hawaiian Islands without some consideration. Present data does not support the near future use of sea water, or brackish or basal water of high salinity levels for domestic, municipal or high quality industrial uses.

SEA WATER

The most unlimited source of water, without relation to quality, is the vast area of ocean that surrounds the Hawaiian Islands. Processing of sea water for domestic, municipal and high quality industrial use has been under study and investigation of a very detailed nature and expensive level for some number of years. A great number of private organizations, as well as the Office of Saline Water of the U.S. Department of the Interior, has spent millions of dollars on the investigation and evaluation of numerous processes, some at laboratory scale, some at pilot plant scale, some at demonstration plant scale, and others at production level. There are numerous sea water conversion plants operating throughout the world, but these have generally been established for research, for demonstration purposes, or in localities where there are practically no other sources of water to meet potable water demands. Investigation, research, and development work has been proceeding at a very substantial level ever since the establishment of the Office of Saline Water by Congress in 1952.

Processes

There are seven basic, or primary, processes by which sea water can be converted to "potable water". These processes are:

- a. Distillation processes
- b. Vapor compression distillation
- c. Humidification
- d. Freezing
- e. Membrane processes
- f. Ion exchange
- g. Hydration

There are variations of several of these processes. For example, under distillation, there is long tube vertical distillation, a multi-effect, and a multiple stage distillation. The membrane processes include:

- a. Reverse osmosis
- b. Electrodialysis
- c. Transport depletion

A detailed discussion of the technical differences, the technical stage of development and the technical problems of the various processes is not appropriate for this report. For a more complete, but simplified explanation of the various processes, the publication entitled "The A-B-Seas of Desalting" by the U.S. Department of the Interior, Office of Saline Water, is recommended.

Economics of Sea Water Desalinization

Technically it is possible by several of the above methods to produce fresh water from sea water. To do this at an acceptable cost level is, however, extremely difficult. Generally, to be acceptable to those who must pay for water or its development, fresh water must be produced from sea water at a cost that is compatible to the cheapest other alternative.

Presently, in excess of 50 million gallons of fresh water is produced daily throughout the world from sea water. Practically all of the numerous plants involved in the production of the 50 MGD costs of water produced are in excess of \$1.00 per thousand gallons, except where energy is available at a very, very low cost. The concentration of salt and saline water, the cost of energy and the scale economies of the desalting plant size are the primary factors influencing the cost of water produced.

Studies "projecting costs" indicate that a sufficiently large plant operating on a low enough energy cost, a condition probably not available in Hawaii for some time to come, could produce "potable water" at costs of less than \$0.50 per thousand gallons. There is no evidence at the present time that any current plant operating on sea water is producing fresh water at this cost level. Other alternatives of water supply in West Maui are substantially under this figure.

BRACKISH WATER

The processes utilized for the desalinization of sea water can, of course, be utilized for the desalinization of brackish water. In the case of West Maui, substantial amounts of brackish water, of variable salinity, are available in the so called Ghyben-Herzberg lens, which is the "basal aquifer".

Processes

The membrane processes and ion exchange are the processes most applicable to the treatment of brackish waters. The effectiveness and the cost of these processes are dependent on the two basic parameters of salinity level and energy cost.

The other processes are generally not considered adaptable because they involve a change of state of water with the result that energy requirements are very close to those of sea water conversion process.

Economics of Brackish Water Desalinization

The electrodialysis process is the most advanced of the membrane processes at this point in time. In this process, the amount of energy required is a function of the amount of salt to be removed in the process. Here again, costs of treatment are directly related to the costs of electric energy. The additional problem related to brackish water is that its chemical analysis varies greatly. Variations in chemical content require great versatility of units and also technical problems of pre-treatment, scaling, brine concentration limitations and multiplicity of stages.

There is also a problem for any given installation should there be a change in the chemical quality of the water, which can happen with supplies from the basal aquifer where over-pumping, drought periods, sea water infiltration or other factors vary the mineral concentration.

The ion exchange process does not have the energy cost problem related to other techniques, since it is in essence a chemical exchange process. However, the resins which are the media of ion exchange are subject to exhaustion and require periodic regeneration, the period of which varies with the mineral content of the water being treated. To date, regeneration costs have limited ion exchange to certain applications.

GENERAL COMMENTS

To give some realistic basis to the above comments, the following quotation is taken from a paper entitled "Current Technology of Multi-Stage Flash Evaporators" by A. Steinbruchel, presented at a seminar entitled "Desalination: Methods and Applications", held at the University of California, Berkeley, March 24 - 28, 1969

"Predicted or extrapolated water costs from desalting plants have been very misrepresentative, to say the least. To put some uniformity in accounting cost of auxiliaries on water production cost, the office of Saline Water has put forward some ground rules for assessing itemized cost as a part of the desalted water cost.

"All of the above listed desalting plants are dual purpose installations which utilize low cost turbine extraction steam as heating source.

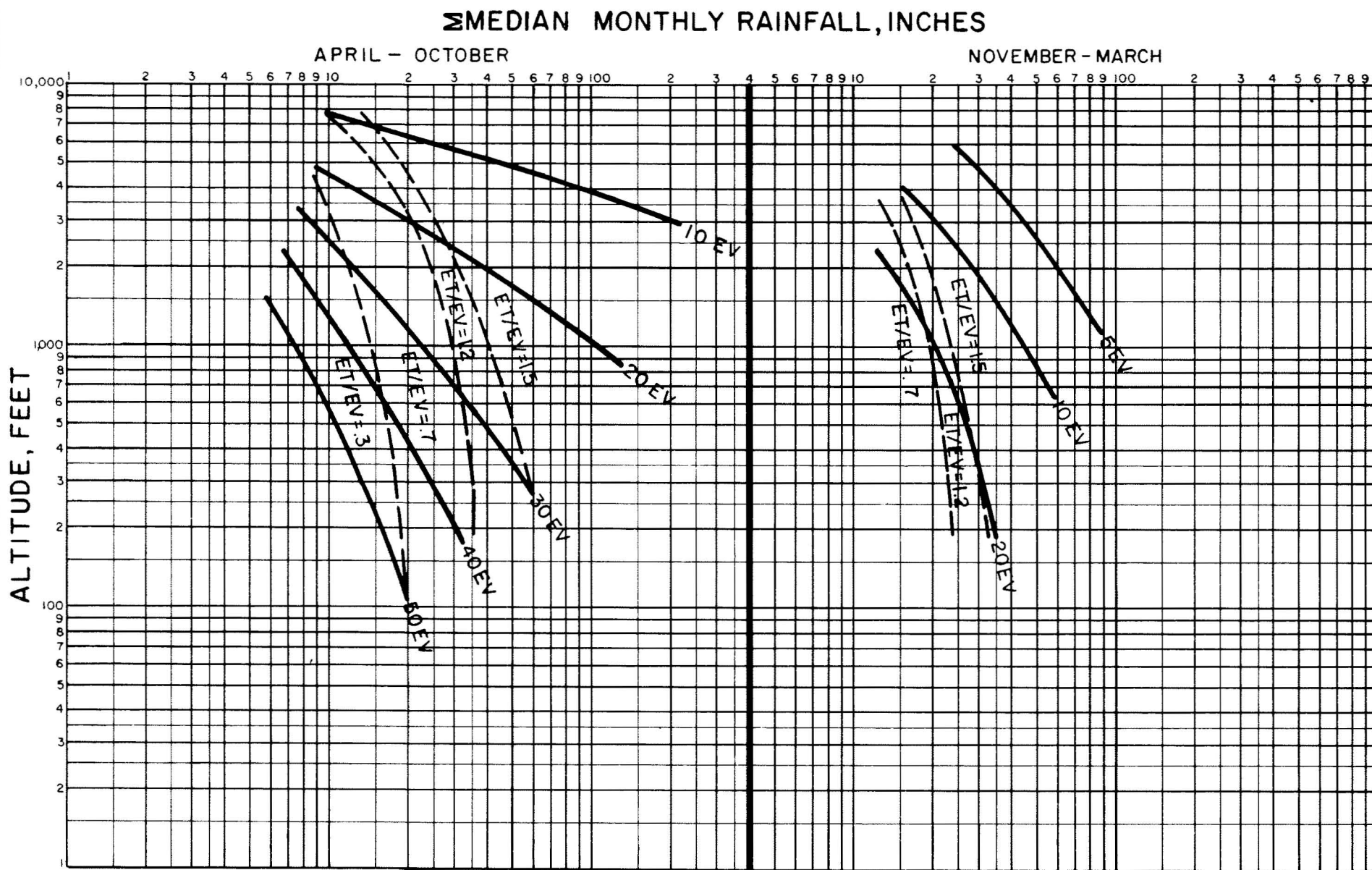
"The steam cost used by these plants varies from \$0.15 to \$0.31 per million BTU, depending on the type of power plant and pressure of heating steam to the desalting plant.

"In single purpose desalting plants where the steam is to be generated by a boiler serving only the desalting plant, production costs of the desalted water are considerably higher, thus single purpose plants usually optimize at a higher thermal performance ratio."

The conclusion, derived from most recent data and discussions at the Berkeley seminar, is that the desalinization of sea water is not a foreseeably applicable technique to provide for the water needs of West Maui.

APPENDIX

Evapotranspiration Estimate



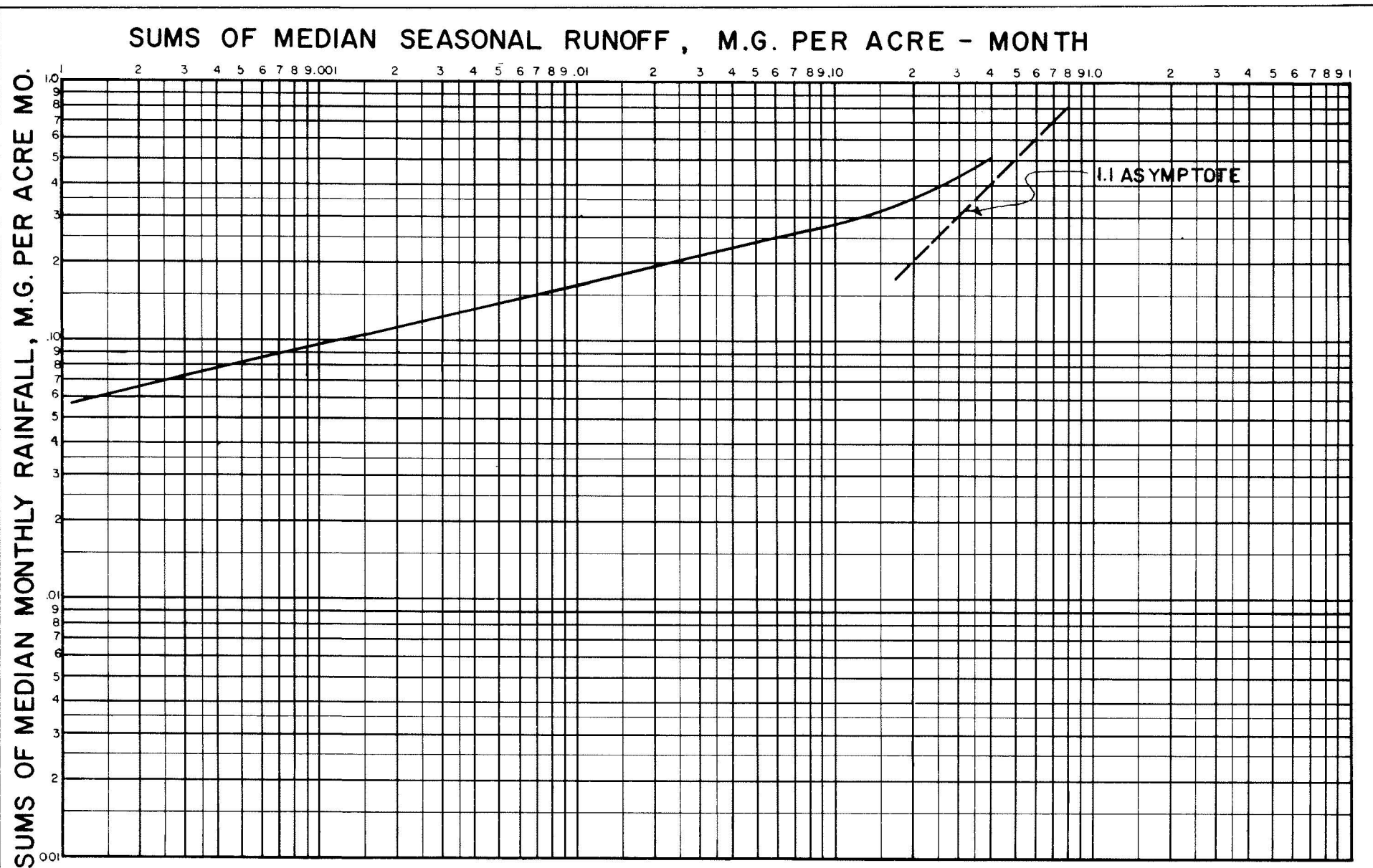
SOURCE: I. AMFAC INCORPORATED

EVAPOTRANSPIRATION ESTIMATE

APPENDIX

Unit Rainfall -- Runoff Plot

Appendix 7



SOURCE: I. AMFAC INCORPORATED

UNIT RAINFALL-RUNOFF PLOT

FROZEN
3.06.09

COUNTY OF MAUI

A WATER SOURCE DEVELOPMENT
PLAN FOR LAHAINA DISTRICT

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COUNTY OF MAUI

A WATER SOURCE DEVELOPMENT PLAN
PLAN FOR LAHAIHA DISTRICT

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